Class number 629.13.014.48 (43) Horten

R.A.E. Report No. F.A. 259/1
Tech. Note No. Aero.1703
October, 1945

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

The Horten tailless aircraft

by

K.G. Wilkinson, B.Sc., D.I.C.

SUMMARY

In March this year a C.I.O.S. team visited the original home of Horten aircraft at Bonn, and brought back information on the recent activities of the brothers Horten which revealed that their development of the flying wing type had reached an advanced stage. Several powered types of great interest had been built and flown, and a six engined flying model of a transport plane half completed.

Later on the Hortens were interrogated in England and a party from R.A.E. followed this up by visiting the Horten factories and flight test centres in Germany in an attempt to find and preserve some of the more useful aircraft. The trip was disappointing in that all the power aircraft except the half completed H VIII were found to be destroyed. One glider was however brought back.

Finally, in September, a party* was sponsored by the Tailless Advisory Committee to visit Germany for further discussion with the Hortens and others interested in tailless problems. The following note is the result of a collation of all the interrogation reports on the Hortens and is an attempt to present a consistent and fairly complete account of their work.

---

* Prof. Hill	(Part time)
S/Ldr. Kronfeld	(A.F.E.E.)
Messrs. Prower	(General Aircraft Ltd.)
Watson	(Armstrong Whitworth Ltd.)
Lee	(Handley Page Ltd.)
Wilkinson	(R.A.E.)

LIST OF CONTENTS

Page

1. Introduction 4
2. Brief historical survey 4
3. Brief description of the Horten aircraft 6
   3. 1 General lines of development 6
   3. 2 **Horten I** 7
   3. 3 II 7
   3. 4 III 8
   3. 5 IV 10
   3. 6 IVb 13
   3. 7 V 14
   3. 8 VI 17
   3. 9 VII 17
   3.10 VIII 20
   3.11 IX 21
   3.12 X 25
   3.13 XI 26
   3.14 XII 26
   3.15 XIII 26
   3.16 XIV 27
   3.17 Parabola 27
   3.18 Projected jet bomber 28

4. How the Hortens design their aircraft 28
   4.1 Wing section design 28
   4.2 Calculation of aerodynamic centres 30
   4.3 Fixing the layout 31
   4.4 Control design 33
   4.5 Flight stability 34
   4.6 Undercarriage design 34
   4.7 Stressing 34
5. Comments on some aerodynamic aspects of the Horten designs 35
   5.1 Stability and control in unstalled flight 35
   5.2 Behaviour at the stall and recovery from the spin 36
   5.3 Tests on laminar flow 37
   5.4 C_L max 37
   5.5 Waggle tip control 38

LIST OF APPENDICES

Appendix

Centres of Horton activity I
Flight test report on the H II II

LIST OF TABLES

Table

Data sheet for Horten Aircraft 1
Wing sections from the H IV II
Wing sections from the H IVb III

LIST OF ILLUSTRATIONS

	Fig.
General arrangement of H I and H II	1
General arrangement of H III	2
Pictures of H III and Parabola	3
Pictures of powered H III	4
General arrangement of H IV	5
Pictures of H IV	6
Pictures of drag rudders	7
Pictures of control balance	8
Wing sections of H IV	9
Wing sections of H IVb	10
Control mechanism	11
General arrangement of H V	12
Pictures of H V	13
General arrangement of H VI	14
General arrangement of H VII	15
Pictures of H VII	16
Pictures of drag rudders	17
General arrangement of H VIII	18
General arrangement of H IX	19
Pictures of H IX V.1	20
Pictures of H IX V.2	21
Pictures of H IX centre section	22
General arrangement of Parabola	23
Pictures of H XIII	24
Sketch of H X	25
Diagram of waggle tips	26
Pictures of waggle tip	27
Mechanism of H IX spoiler	28

1 Introduction

The activities of the Horten brothers in the design of tailless aircraft have been reported at various times in the German journal "Flugsport" and translations have been published by R.T.P. during the war. Their more serious efforts based on early experience with gliders, were not well known until a C.I.O.S. team investigated the Horten home at Bonn (March 1945) and interviewed Herr Berger who supplied information of many of their later projects.

After the cessation of hostilities, the Horten brothers were interrogated in England (May 1945) and in the first two weeks of June 1945 the writer visited Germany, with the Hortens, and investigated their centres of activity. Final interrogation was carried out by a team sponsored by the Tailless Advisory Committee in September. The material from these investigations has been collated and a fairly complete picture of the Horten development is presented in the following report. The complete series of aircraft is described in some detail and the design methods used are summarised. Results from flight tests on performance and handling are given where possible, but no written evidence in the way of reports or calculations were found by any of the investigators. This feature is unfortunate since many of the figures quoted for performance etc. are dependent on the accuracy of Reimar Horten's memory.

Only one aircraft (the H IV Sailplane) was discovered in the British sector in Germany in a condition suitable for transport to England for test flying. Other gliders were found in the American and French sectors but all the power aircraft were so badly damaged as to be useless.

Illustrations for the report have been prepared from general arrangement drawings of the early gliders (I, II and III), published in the German technical press together with drawings of the later aircraft found in Germany. Photographs were supplied by Reimar Horten or taken by the author.

2 Brief historical survey

Walter and Reimar Horten commenced their experiments on tailless aircraft at the ages of 11 and 10 respectively by building and flying small models. In 1927 they started gliding and in the following years helped the Bonn group at the Wasserkuppe. By 1932 Walter had his C glider licence and an A2 power licence, and Reimar had his C glider licence and had started power flying.

In 1933 they started work on their first man carrying glider which they built in the family home at Bonn. Trials began with bungy catapult launches on level ground; auto and winch launches were tried without much success and finally it was aero towed. About two hours flying were done up to March 1934 and later that year it won a prize at the Rhön gliding competitions as an original design. Longitudinal stability seems to have been fairly good but lateral control was unsatisfactory (due mainly apparently to adverse yawing moments from the ailerons), and longitudinal control became very ineffective at low speeds.

After the 1934 Rhön contest the first aircraft was scrapped and work started on the Horten II which incorporated lessons learned on the H I. This was finished in May 1935 but could not be entered for the Rhön, so a 80 H.P. engine was fitted (Fig.1) and extensive test flying carried out.

At this stage the brothers were called up for military service, but continued to work on their tailless designs and during 1936 schemed the H III and IV (gliders) and the twin engined H V. Two more H II's were built and entered by the Luftwaffe for the 1937 Rhon contests. No great success was achieved because the brothers were out of practice. General Udet was interested in the Hortens work and asked Hanna Reitsch to test an H II, in December 1938, and give an independent assessment. Her report (Appendix II) showed that considerable development was necessary in control design but that the aircraft had some very good features, in particular the behaviour at the stall was good and the longitudinal damping satisfactory. Main troubles were with lateral and directional control.

Whilst studying at the Bonn Technical High School in 1938 and 1939 the brothers organised the construction of a number of H III's which were paid for by the Ministry of Education. Two of the type were entered for the 1938 Rhon contests flown by Blech and Scheidhauer (later their chief test pilot). Remarkable performances were put up by both aircraft. On August 6th Blech climbed to 26,000 ft. in a cumulo-nimbus cloud. He had to abandon his aircraft (probably due to icing troubles) and was unfortunately hit by it and killed on the way down. He had a special fixed auxiliary front aerofoil fitted to his H III to assist in performing tight circles. Scheidhaner also iced up in the same cloud and had to take to his parachute. During this period the H VII, a development of the V (which had been built to the Horten designs and was already flying) was projected but could not be built. Discussions took place with Heinkel and Messerschmitt with a view to engaging Reimar on tailless projects but nothing came of the negotiations.

From 1939 to 1942 the brothers were again in the Luftwaffe and Walter, by devious means managed to get an H IV (a new high aspect ratio sailplane) built at Königsberg where he was stationed. This clandestine construction was discovered by his commander and Walter was sacked.

In 1942 Northrop's work in America attracted attention in Germany and Walter was ordered to restart development. Luftwaffe Sonder Kommando 9 was set up with 200 men, factory premises and Government grants to the tune of £500,000 for getting machinery. Headquarters were at Göttingen and the Peschke works at Minden was used to build Horten designs. (This was a furniture factory which turned over to aircraft components during the war years). Many other dispersed workshops and test and design groups were organised. Construction of the VII was authorised and it was flown successfully in 1943.

Official enthusiasm waned again in 1943 when the quantity order for the VII was cut, but they continued to work without authority and started the H IX as a private venture. Official interest revived when it was half completed and Göring ordered them to finish it quickly. It flew as a glider in 1944 and design work was started on the H VIII which they succeeded in selling to R.L.M. Their high performance glider H VI also flew in 1944.

The powered H IX flew in January 1945 at Oranienberg. It was demonstrated to Göring in March and the Gotha concern got an order to productionise the design and build 20. On March 12th a conference was called at Carinhall at which Göring presided and it was decided that the Chief of the Air Equipment Branch should consider immediate inclusion of Horten development and production work into the Führer's emergency programme. The meeting put on record that it considered the flying wings produced by the Hortens to point the way for future development of all aircraft (presumably excluding rotary wing types). The State Research Council was ordered to organise a group of specialists to cooperate with the Hortens in future development work, and give the brothers all possible support. Production for training purposes was ordered to recommence.

There the story of the Hortens tailless work finishes; a remarkable record of progress made in spite of obstacles. In the early stages work was only kept going by a genius for getting people to work for nothing and in the end continuity had to be achieved in spite of fluctuating official support. In addition to running a very complex and dispersed organisation, the brothers, with assistance on calculations from their sister, had to grapple with aerodynamic and engineering problems on a bewildering variety of aircraft. This side of the work was run mainly by Reimar who remained independent and original in his thought throughout and got little help from outside.

Apart from the design and production of the VII, VIII, and IX, which represented an ambitious series, time and resources were found to pursue the old interest of glider design. By 1945 serious production of the III and IVb had been organised, amounting to about four a month and two new gliders were constructed - the acrobatic H XI and the mass production H XIV sports sailplane, designed to the Olympic Games specification.

Concurrently with this work a new two seater private owners aircraft with a 100 HP engine was designed, and one built and flown as a glider. Serious thought was also being given to supersonic aircraft and tentative steps in this direction were taken with the research designs H XIII and H X.

In reviewing the Horten achievements one cannot help being impressed with the speed of their work and the utter irrelevence of much of it to the German war effort. Prototype gliders were knocked up with astonishing speed with the very minimum of drawings. Although the basic design and general arrangement were soundly worked out by Reimar, detail work was largely settled by the workman on the job with occasional interference from Horten. Peschke was reduced to despair by the Hortens on many occasions because they were always altering details as the design progressed and he could never get his production drawings tidy.

There is no doubt that much of the work on sailplanes was a dead loss to Germany - for example the H VI, H IX and H XIV and the motor sailplane IIId had no connection with military or civil designs and taught no useful lessons. Much of the work was without R.L.M's consent, and Reimar commented that an advantage of dispersal was that R.L.M. could not find out what was going on, or how their money was being spent. An extreme example was the second glider H VI, which was started at Bonn moved to Hersfled when the Allies threatened Bonn and finished just before the Armistice. It was then hidden in a barn where we found it in June 1945. The construction took about 8000 man hours. Reimar said that he preferred building sailplanes because he could do the complete design himself. He resented time spent in supervising staff on his larger projects.

3 Brief description of the Horten aircraft

3.1 General lines of development

From the first the Horten brothers have been of the opinion that the pure flying wing is the most efficient form of aircraft and all their efforts have been directed towards achieving this ideal. They have steadfastly refused to compromise on this issue by fitting fins of any sort, although some of their undercarriage trousers must contribute substantially to the sideforce derivative y_v and so give some of the benefits of a fin. Their later power aircraft have dispensed even with this partial fin. On aircraft with narrow chord wings they have approached the pure wing as closely as possible by putting the pilot in a prone position.

The development of aerodynamic ideas has been almost entirely through flight experiment. No wind tunnel tests have been made on complete models, although they have had access to basic wind tunnel data and research work, for example, on the delay of shock stall on highly swept back wings and tunnel tests on low drag sections. Their general attitude seems to be that tunnel tests take too long and give too little information. A certain amount of their flight testing has been done with instrumentation but they have done nothing as thorough as the current instrumented flight research here and in the U.S.A. The most complete investigation seems to have been on the glider version of the H IX which was instrumented by D.V.L. for lateral stability tests to demonstrate its suitability as a gun platform. Many of the gliders were performance tested to measure drag polars and $C_L$max and tuft tests to show stall development were carried out on three aircraft.

Apart from this, the majority of flight research seems to have relied on test pilots reports.

The following paragraphs give a brief description of each aircraft. A more general discussion of some of the aerodynamic features common to several designs is given later. General arrangement drawings and photographs are given in Figs. 1 - 26 and dimension and weight data in Table I.

3.2 H I

This was built at Bonn during the year 1931 - 1932 and had a flying life of about 7 hours. It had a span of 40 ft. and a wing loading of 2 lb/sq.ft. The control system comprised a central flap giving elevator control and normal ailerons at the wing tip. Directional control was by leading edge drag rudder at the wing tip.

All the control flaps were hinged at the upper surface with a circular arc lower leading edge forming a seal with the wing. There was no aerodynamic balance.

The wing section was symmetrical throughout and thick enough (20% C) at the centre section to house most of the pilots body. His head projected from the upper surface and was faired by a perspex cockpit cover. A rubber mounted skid formed the undercarriage.

As remarked in para. 2 the control system was unsatisfactory and was changed on subsequent aircraft. It seems to have been impossible to stop a slow speed turn by use of aileron alone and the drag rudder, which at first was on the lower surface only, was ineffective and caused a nose down pitching moment. When an upper surface flap was added to cure this the braking action became too fierce and springs had to be incorporated to make the control heavier. Reference was made to a yawing tendency at low speed which could result in an uncontrollable turn through 360°.

3.3 Horten II

This aircraft was of the same general layout as the H I but with sweepback increased from 19° to 26° and the lateral and longitudinal control combined in an elevon. Inboard flaps extending from elevon to centre section were used to increase maximum lift and drag for landing.

The first version was completed as a glider and the second fitted with an 80 HP Hirth engine driving a pusher propeller. In this aircraft (Fig. 1) the pilot was seated in a reclining position and completely contained in the wing contour; a maximum level speed of 210 k.p.h. was achieved. Subsequently three more gliders were built, the last being completed in 1937 after which the type was abandoned in favour of the H III.

The root wing section was changed from the 20% symmetrical H I type, to a 20% section with reflexed camberline(zero C_{m_0}) changing along the span to a symmetrical tip section. A balance tab was fitted to lighten the controls which were all pushrod operated.

The structure was in three parts, as in all subsequent Horten designs. The centre section being of welded tube and the outer panels of wood with a D-nose spar. The wheel undercarriage had brakes and the front wheel was retractable.

Drag rudders consisted of leading edge flaps (as on the Horten III Fig.3) opening against a spring.

Appendix II is a translation of Hanna Reitsch's report on one of the H II gliders. It is clear from this that lateral and directional control were still only partially satisfactory although characteristics at the stall were excellent. This feature is remarkable, for although a wing twist of 8° was used the effect of the high taper and sweepback might be expected to overpower the beneficial effect of twist in delaying a tip stall.

3.4 H III

The first H III was built at Templehof Berlin, in 1938 and the second (H IIIb) was built by Peschke Flugzeugbau, also in Berlin.

The main changes from H II were increased span (20 m) reduced sweepback (23°) and modified lateral controls. The outer wing panels this time had three movable flaps : the innermost was again a landing flap but the outer pair were geared so that the outer flap had a large range of upward deflection and only slight downward movement and the inner flap large downward movement and slight upward movement. This arrangement reduced unfavourable yawing moments due to aileron by making use of differential aileron movement, but avoided the change in longitudinal trim by the opposing differential of the inner flap pair. In high speed flight the nose down trim was provided mainly by the inner elevon section moving downwards the outer flap deflecting only slightly; this had the advantage of relieving the tips of torsional loads at high speed. Aerodynamic balance was again by geared tab on sub types IIIa and b but on III d, f and g the outer flap had a 20% Frise nose: out of balance aerodynamic loads on the elevators were trimmed by a rubber bungy trimmer.

Drag rudder design remained the same as for H II.

H III seems to have been a successful and useful type, for 14 were built altogether and several different sub-types developed. Production of some of the sub types was still going on in 1945. The following variations on the original theme were produced:-

IIIa Original design (Fig.2).

IIIb Similar, but with outer elevon flap not extending to the wing tip.

IIIc Type (a) but with a fixed front plane. One of these was built, for the 1938 Rhön contest. Very little flying experience was obtained. The idea was to improve $C_L$max.

IIId Standard wings fitted to a special centre section with 32 H.P. Volkswagen engine and folding propeller. The idea was to produce a high performance sailplane with auxiliary engine for take-off and climb, which could be shut off for soaring without impairing the performance as a sailplane.

Centre sections (Opel engine with gear drive) were being produced at Tübingen at the rate of two a month. 12 partly finished were in the Workshop in June 1945. Finished parts were sent to the Hornberg and assembled with wings made at Dorn[illegible]dorf.

Fig. 4 shows some views of the power H III centresection with a belt drive to the propeller. Fig. 3 shows the complete aircraft.

Performance with power was stated to be

Ground run	70 metres
Rate of climb	2 m/sec.
Cruising speed	110 k.p.h.
Max. speed	130 k.p.h.

The engine installation was taken straight from the Volkswagen complete with exhaust system and electric starter; it weighed 240 lb.

IIIe H III glider with waggle tips. The scheme is sketched in Fig.26. On this aircraft, remains of which were found at Göttingen, the tips were operated directly by the pilot.

IIIf Same as IIIb but with prone position for the pilot. A specimen of this type was found by the writer at Gut Tierstein with modified controls. The outer flap had a Frise nose, (as on H IV), spoiler type drag rudders were fitted in place of the usual leading edge split flaps, and H IV type dive brakes installed.

The prone piloting position eliminated the need for the head fairing used on the other H III's and gave the pilot a much better view.

IIIg Special two seater centre section with tandem seats. Specimens were found at Zimmern and Hornberg. This type was used for training purposes.

No independent opinions are available on the flying qualities of the H III series but Reimar Horton was insistent that it was a very straight forward aircraft from the pilots point of view. He stated that any glider pilot with five hours experience could be safely sent off solo in an H III.

3.5 H IV

General

The H IV represented the Hortens mature thoughts on sailplane design. The span was the same as that of the H III but aspect ratio was increased from 10.7 to 21.1 and the control system further developed. In order to retain their finless wing layout and get the maximum aerodynamic efficiency, the pilot was put in a prone position with his body in a 27% thickness ratio egg and his knees and legs in a small leg well, which also supported the rear skid (or wheel in the case of the IV b.)

A specimen of H IV was found at Göttingen in good condition and was brought back to R.A.E. for test flying. It has completed 500 hours flying since its construction in 1942 including a cloud flight of $1\frac{1}{2}$ hours on instruments : such a flight demonstrates that stability and control and the comfort of the prone position must be satisfactory.

Controls

The three stage control flaps were all geared to the spectacle type control wheel (Fig. 11) and operated on the same general principle as the earlier two flap control on the H III. The following table gives the (measured) flap movements corresponding to full control by the pilot.

Control movement	Control Flap Angles					
	Port			Starboard		
	Tip	Centre	Inner	Inner	Centre	Tip
Wheel fully forward	12	14	14	17	14	11
Wheel fully back	-16	-14	- 3	- 4	-14	-11
Wheel to starboard	+16	9	13	- 2	- 7	-28
Fully starboard and fully back	0	-10	- 2	- 5	-17	-33

It will be seen that the outer flap works principally as up going aileron whereas the "climbing elevator" action comes mainly from the middle flap and "diving elevator" action from the inner flap. Down going aileron, needed to neutralise pitching moments, comes from the inner and middle flaps together.

The centre and inner flaps were unbalanced, with round noses, the tip flaps Frise balanced with a skew hinge giving 39% balance at the inboard end and zero balance at the tip. This scheme, shown clearly in Fig. 8 gave the required aileron yawing moments without making the control flap at the tip vulnerable when a wing tip scraped the ground.

Drag rudders were of the upper and lower surface spoiler type placed immediately ahead of the outer control flap; the upper surface spoiler had a vented web (Fig. 7). To open the rudders the pilot had to press with his toes, moving the foot from the ankle against a spring loading on the pedals which gave "feel" to the control.

By pressing both feet together he could open both rudders simultaneously, thus giving extra drag for glide control. Rudder operation was said to cause no buffeting of the control flaps. The movement transmission from the pilots pedal included a cam plate (Fig. 11) cut to give no rudder movement for negative movement of the pilots foot (i.e. pressure on the opposite pedal) and an approximately linear relationship between pedal movement and rudder projection for positive movement (i.e. pressure on the pedal).

All controls were operated by push rods, the inner and central flaps and the drag rudders being moved by skew-hinge cantilevers; the system is illustrated in Fig.11. In the IV b the skew hinge principle was extended to the outer flap operation also. The method of operating the control flaps was simple to construct and eliminated all external control horns.

Longitudinal trim was obtained by an internal bungy "spring" which can be adjusted to take any out-of-balance aerodynamic loads on the elevator control.

There were no landing flaps but large spoiler type dive brakes were provided, which could also be used to give variable drag for glide path control.

Wing design

The H IV used reflexed cambered sections (zero C_{m_0}) of R.A.F. 34 type, changing to a symmetrical section at the wing tip. Sections at four stations on the wing are given in Fig. 9 and tables of ordinates in Table II. The Horten method of deriving wing sections is described later (para. 4.5). Fig. 9 also shows the measured washout distribution; this was such that leading and trailing edges were approximately straight (second power distribution) but this was fortuitous as the actual design formula was more complicated (para. 4.2.1).

The large wing dihedral of 5° was used to give adequate wing tip clearance. Reimar Horten considered that aerodynamically this might be on the large side but advisable for practical reasons. It should be remembered that both the H III and H IV have an abnormally low value for the lateral relative density μ so that unusual values of l_r and n_v would be permissible without dynamic instability resulting.

Flying qualities

Performance was measured by flying the H IV against the D 30, a conventional high performance glider which had been carefully performance tested by D.V.L. to form a "standard". The essence of the method was to tow both aircraft up together and let them glide down from about 10,000 ft. at a series of flying speeds, measuring the relative height photographically, at intervals. From these tests the best gliding angle of the H IV was found to be 1 in 37 and the minimum sinking speed 1.7 ft/sec. Minimum sinking speed was slightly less than the D 30 but at high speeds the D 30 was better.

Scheidhauer, Hortens' chief test pilot, has done the majority of the flying in Horten IV's (about 1000 hrs) and his comments are worth recording. He is a strong advocate of the prone position - in his own words "it has nothing but advantages". All H IV controls he described as very light, he flew the glider with "two fingers". The elevator was apparently rather sensitive compared with the aileron but not unpleasantly so. Aileron application produced no adverse yaw - a definite improvement after the II and III - and could reverse a 45° banked turn in 5 secs. at 70 - 90 k.p.h., which is better than the average sailplane. Longitudinal stability he thought satisfactory but he commented on a "wiggle" which was produced by flying through gusts; this is apparently a sharper pitch response than for a conventional sailplane, but well damped, quite harmless and requiring no corrective action by the pilot. A true stall could not be produced with normal elevon adjustment because of increasing static stick fixed stability at the stall, which used up available elevator power before the wing tips were stalled. Spins could only be produced by applying full aileron and rudder with the stick hard back; recovery was easy.

Stability and controllability on tow were excellent. Scheidhauer described a competition in which a number of sailplanes were aero-towed from Grunau through the very turbulent air in the "standing wave" from a nearby mountain; the rough air had to be negotiated on tow to get to the area of rising currents. All the instructors from the school at Grunau were flying conventional sailplanes and broke their tow lines without exception. Scheidhauer in his H IV managed to get through and soar in the standing wave. He attributed his success partly to his own skill and partly to the good controls of the H IV plus his ability to use the tip rudders together to check surging in the tow rope.

Take-off seems to present some problems to a pilot new to the aircraft. It seems that the short undercarriage base, responsive elevator and small wing tip clearance can produce a very erratic take-off if the pilot is not smooth and precise in his control movements.

Structural features

Construction followed the normal Horten practice, but the wing panels were made with detachable tips of sheet elektron. This was necessary because the narrow chord at the tip made accurate construction in wood very difficult. The centre section was of welded steel tube, with perspex nose and a large jettisonable access cover behind the main spar (Fig. 6).

The front skid was retractable and fitted with a wheel which automatically dropped off as the skid retracted.

The pilots harness was modified from the original version shown in Fig. 6, being a single broad strap passing under the buttocks. This was released by the same handle that jettisoned the access cover. The pilots parachute was stowed in a pocket on the cover and connected to the pilots harness by short strops. In this way the pilot was relieved of the weight of the pack, which would otherwise have caused some discomfort on a long flight.

Equipment

Flying instruments included a low reading A.S.I. driven by a venturi, electrical turn and bank indicator, sensitive variometer, high reading variometer, altimeter and clock.

Oxygen equipment comprised two bottles, pressure gauges, reducing valve and economiser and provision was made for electrically heated clothing. Ventilation was under the pilots control.

Prone position bed

Pilots weight was taken mainly on the chest and knees. The knee well could be adjusted for varying pilot size and a chin rest with adjustment for height was provided.

The pilot was prevented from sliding forward by shoulder rests and the reaction of his thighs against the knee well.

Comfort appeared to be satisfactory when we tried the bed but elbow and shoulder movement was restricted which constrained one to stay in the same position all the time.

3.6 Horten IV b

General

Superficially the IV b resembles the IV very closely but the aerodynamic changes were a fundamental experiment. The Hortens intended to produce a laminar flow sailplane with superlative high speed performance - in this they were partially successful but they sacrificed too much on the stability and control to make the venture a real success.

Production had been started, prematurely, at the rate of about two a month.

Aerodynamic design

Wing sections were derived from the Mustang section which had been measured by D.V.L. from captured aircraft and tunnel tested. The Hortens were excited by the low tunnel drag figures and designed the H IVb to exploit them. The root section was the original Mustang profile, changing to an uncambered section with the same fairing shape but reduced thickness at the tip. Wing twist was reduced (compared with the IV) to 5.6° to get the greatest spanwise extent of laminar flow, and sweepback reduced by 2° to get the C.G. farther back relative to the mean chord (this was necessary because the aerodynamic centre of the basic wing section was farther aft). It is interesting that although C_{m_0} was not zero for the root section, the high aspect ratio enabled the glider to be designed to trim, elevons neutral, at the required top speed (140 k.p.h.) without needing excessive twist.

Structure

The wing structure ahead of the main spar was a ply sandwich monocoque with Tronal filling. Tronal was an expanded wood with specific gravity 0.1 to 0.09, invented by a Dr. Barschfeld of Dynamit A.G., Troisdorf, (near Cologne). The sandwich was made up on moulds, with outer ply 1mm thick and inner ply 0.8 mm; the filling was 20 mm at the root tapering to 5 mm at the tip. The nose sections were stuck onto the front of the main spar with supporting ribs every 2 metres. Between the main and rear spars normal ply covering was used, insufficient Tronal being available for sandwich construction all over.

Waviness in a chordwise direction was not controlled or measured. Sag (spanwise) between ribs had been measured on the IV and eliminated on the IV b. Special care was taken to keep dust off the wings; wing dust covers were made and all handling was done with gloves on.

Control circuit mechanism remained the same except for the outer flaps which were also operated by a skew hinge lever on the IV b. The dive brakes were moved back to the rear spar to suit the revised wing structure.

Performance

No transition measurements were made on the IV b but it was flown against a calibrated IV and the following relative sinking speeds measured.

48.5 mph	up to 80 k.p.h.	no difference		
60.5 mph.	at 100 k.p.h.	IV/1 m/sec.	IVb 0.85 to 0.9 m/sec.	(2'·9"-3'·0")
73.0 mph.	120 k.p.h.	IV 1.40 m/sec.	IVb 1.20 m/sec.	(~4'·0")

The change of section raised the stalling speed from 45 k.p.h. on the IV to 60 k.p.h. on the IVb.
[36.2 m.p.h.]
27.2 m.p.h.

Handling Characteristics

These were very unsatisfactory. A wing tip stall occurred followed by wing dropping and spinning. The first aircraft crashed for this reason after the pilot got into trouble in a cloud. An attempt was made to improve matters on the second glider by clipping the span from 20.25 metres to 18.5 metres but results were disappointing. As a cure on the final design a reversion to the old H IV tip section was proposed, the theory being that section stalling characteristics were bad due to the sharp nose radius. Partial breakaway behind the maximum thickness point was suspected, aggravated by spanwise boundary layer drift which rendered the elevon ineffective. Horten thought the small wing tip Reynolds number made the use of low drag sections inadvisable.

3.7 Horten V *

General

The H V was designed from the outset as a powered aircraft using two Hirth H.M. 60 R motors driving oppositely rotating propellers. It had a span of 52.5 ft. aspect ratio 6 : 1 and a quarter chord sweepback of 32°. Engines were completely buried and drove propellers on extension shafts raised relative to the engine crankshaft and driven through a reduction gear. The undercarriage was of fixed tricycle type with castoring nose wheel and trousered main wheels. The nose wheel actually took 55% of the static weight when on level ground.

Three examples were built. The first, built at Ostheim in 1936 was constructed of plastic material with riveted sheet plastic covering. Pilot and passenger were contained entirely in the wing contour and the nose wheel was retractable. This aircraft crashed on its first flight, due mainly to its unorthodox waggle-tip control. The second version used more normal control methods and conventional construction, it was started in 1937 and flew successfully. In 1941 it was completely rebuilt (Fig. 12 and 13) as a single seater, but retained the same control system.

Controls

In its original form the H V was fitted with waggle tip control (Fig. 26) in which the fore and aft sweep of the wings tips was geared to the stick, producing incidence change by a skew hinge arrangement similar to that illustrated in Figs. 26 and 27. The aircraft crashed on its first flight due to the control taking charge after a bounce during landing. The reason for the accident was obscured by a failure of one engine but the control system was not regarded as satisfactory by the

Hortens who later developed the idea further on an H III. They consider that damping is necessary to prevent the tips oscillating under suddenly applied acceleration (as occur during take off and landing).

The second aircraft in both its forms had a two stage elevon control rather similar to the H III. Maximum control deflections were as follows:-

Control column position	Port		Starboard	
	Outer	Inner	Outer	Inner
Fully left	- 20°	- 2°	+20°	+ 2°
Fully forward	+ 5°	+30°	+30°	+ 5°
Fully back	- 40°	- 5°	- 5°	-40°

The outer control flaps had a 20% Frise noses and assymmetrically geared tabs to compensate the non linear moment characteristics of the nose balance. The inner flap pair had round noses.

Split trailing edge flaps were fitted to the centre section, the flap between the engines lowering to 60° and the part outboard to 45°. The inner elevon flaps drooped to 30° when the centre section flaps were lowered and still operated as elevons about this new zero position. The idea of using graded flap deflections originated from a hunch of the Hortens that the sudden discontinuity and greater spanwise flow with ungraded flaps might cause stability and control troubles. They later found that this fear was unfounded and gave up the graded deflection principle.

Rudder control on the second two aircraft was by split nose flaps of the H III pattern (Fig.3).

Flying characteristics

A great deal of flying was done on the second and third H V's, including about twenty flights on the latter in 1943 by Prof. Stüper of A.V.A. Göttingen. We questioned him extensively about his impressions of the aircraft (Sept. 21st 1945), because it was the most recent Horten product he had flown. The Hortens themselves had lost interest in the H V because later designs incorporated many improvements. Stuper had also flown the H IIId with Walter Mikron engine.

Tests at A.V.A. were undertaken at the request of D.V.L. who wanted information on single engine characteristics and an unbiassed comparison between tailless and conventional handling qualities. Stüpers comments were as follows:-

Stability

Longitudinal dynamic stability was good and no fundamental difference from a conventional aircraft could be noticed. In rough air he thought it had a more abrupt pitch response than normal, which was only a disadvantage if gun platform steadiness was needed. (Walter Horten thought this effect might be due to low wing loading (6 lb/sq.ft.) on the H V and Stuper agreed that this might be so).

Lateral stability appeared satisfactory. No tendency to "dutch roll" instability was found and no erratic changes of heading due to low n_v and y_v were noticeable. Stüper was in fact expecting trouble from this source but failed completely to find any. He added that his impressions were purely qualitative as they had no time to instrument the aircraft.

Controls

Controls were light and effective, with the exception of the rudder which was heavy and not effective enough. Aileron was heavier than the elevator "in the ratio 4 : 3". With the stick back, aileron movement was restricted, which Stüper thought a bad point since plenty of aileron was useful in an approach in gusty weather. The aircraft was in trim virtually over the whole speed range without movement of the elevator trimmer. When flaps were lowered there was a slight nose heavy tendency which could easily be held.

Summing up, Stüper said that aileron and elevator control were quite normal but rudder control needed improvement.

Stall

Behaviour at the stall (flaps down) was very satisfactory, the nose dropped gently and the aircraft gained speed. Wing dropping could be induced if the aircraft was stalled in a yawed attitude but normally the wings remained level and ailerons still effective, though restricted in movement. The stall was reached with the stick not quite fully back; only one C.G. position was tested. Stalling speed was about 70 k.p.h.

Single engine flight

Flight on one engine was possible, without rudder, at 120 k.p.h. by flying with 10° bank and 80% aileron. Rudders were not used much because they were so heavy, although Walter Horten claimed that at 130 k.p.h. single engine flight could be maintained on rudder only (engine nearly at full power) if the pilot was strong enough.

Landing and take-off

Ground manoeuvring was easy using throttles and wheel brakes. During take-off the aircraft could quite easily be kept straight until the drag rudders became effective, and flew itself off the ground without assistance from the pilot - in fact it made very little difference what the pilot did with the controls during take-off. There was no tendency to buckett or bounce during the ground run. R.L.M. require that for normal tricycles, it should be possible to lift the nose wheel before take-off speed is reached; Walter Horten thought this was unnecessary if the aircraft would fly itself off. Landing was quite straightforward and normally the aircraft settled down on all wheels at once. Stüper thought it was not possible to land on the main wheels first because the ground incidence was too high.

Baulked landing

Stüper had done some tests of take-off performance with flaps down, which resulted in his flying into a hangar and terminating the A.V.A. test programme. Apparently he landed and immediately (Walter Horten said not immediately) opened up to take-off again - after 530 metres he was 8 metres high and at that point entered the hangar. The airborne distance was about 150 metres.

Although the split flaps in front of the propellers caused poor thrust, there were apparently no vibration problems.

Summarising his impressions on the H V, Stüper said that it was hardly fair to compar it with conventional aircraft with many years more development behind them but it was, nevertheless, a good example of tailless design and a perfectly practical aeroplane - if anyone wanted tailless aeroplanes. His main suggestion for improvement was in the rudder control.

3.8 Horten VI

In general layout this aircraft was very similar to the H IV. The span was increased to 24 m (78.7 ft.) accompanied by a decrease of 5% in wing area, giving an aspect ratio of 32.4.

The object in building the H VI was to achieve the most efficient high performance sailplane regardless of cost. Two were built and the first was tested late in 1944. It was performance tested by the relative sinking speed method previously described, using a calibrated H IV for the second glider. The Hortens were very pleased because it was better than the D 30 (same span and wing loading) over the whole speed range.

Aerodynamically there were no new features of special interest compared with the H IV. Wing sections and control systems remained the same. The structural design had to be refined in order to get sufficient bending strength in the very thin cantilever. The main spar was made up of laminations of plain wood and "Lignofol" (a compressed impregnated wood) to give extra strength at the root, and a special wing root fitting using four taper pins in place of the normal two was devised to distribute the concentrated loads at the root. The torsion box design was modified also to increase the wing torsional stiffness, since at high speed it had been found that an unstable short period longitudinal oscillation, involving wing twist, could develop. The speed at which the damping of this oscillation became zero on the H VI was found to be about 180 km/hr.

The H VI is of interest only as a high performance sailplane for record breaking purposes. It is too costly and difficult to handle for general use.

The second aircraft of this type to be built was found intact, by the writer, near Hersfeld; the first aircraft was found destroyed near Göttingen, where it had been flying.

3.9 Horten VII

General

The H VII was projected in 1938 and the first of the type was built by Peschke at Minden in 1943. It bears a general resemblance to the modified H V in layout and control design and used the same outer wing panels: the span was the same (16 m) the sweepback slightly greater (34°) and aspect ratio 5.8 instead of 6.1. Its function seems to have been that of a high speed two seater communications aeroplane and trainer for tailless pilots. Engines were Argus AS 10 C of 240 HP. Fig. 15 shows the general arrangement and Fig. 16 gives some pictures of it on the ground and in flight.

Altogether two were completed and flown and a third was nearing completion at Minden when the district was occupied by the Allies. Two aircraft were damaged beyond repair and the third fell into Russian hands at Eilenburg.

Controls

Single stage elevon control was used on the H VII with 25% Frise nose and geared tab. Inboard of the elevons was a plain flap and in the middle trailing edge split flaps extending for the full width of the centre section. Initially the graded flap angle principle was used, the part between the engines opening to 60°, between the engine and the outer wing panels to 45°, and the plain flap on the wing lowering to 20°. When R.L.M. ordered the design in quantity however they asked for it to be simplified and for the landing speed to be raised to give pilots more realistic training for high speed aircraft. The plain flap was accordingly locked up on the second aircraft and omitted altogether on the series production model.

Plug spoiler drag rudders of the H IV type (Fig.7) were used on the first aircraft. These tended to suck open and had to be held closed by springs. They were not very satisfactory from the point of view of control forces and feel, and after about 10 flights they were scrapped and replaced by a new "trafficator" design. This was simply a bar which projected 40 cm in a spanwise direction from the wing tip when rudder was applied and retracted flush with the wing surface when not in use. Fig. 17 shows the rudder in open and closed positions but without the vent holes which were cut to adjust aerodynamic balance. The vent holes allowed flow through the bar and deflected the flow sideways to generate a self closing aerodynamic force. This was supplemented by a spring loading and the two components adjusted to give satisfactory feel on the rudder bar. This type of rudder was claimed to be cheap and easy to make and generally more satisfactory than previous designs.

Structure

This followed normal Horten practice, the centre section being of welded tube construction and the wings of single spar wooden construction with ply covering.

The undercarriage was a completely retractable four wheel layout, the front wheel pair taking about 50% of the total weight when resting on level ground.

The constant speed airscrews were driven through extension shafts with a thrust ball bearing and rubber flexible coupling at the engine end and a self aligning ball bearing at the airscrew end mounted on a cantilever from the main structure.

Aerodynamic design

Outer wing panels were of the same aerodynamic shape as those of the H V. At the centre line the section was 16% thick with 1.8% camber (zero C_{m_0}) graded to 8% symmetrical tip sections. Wing twist was 5°; 2° linearly and 3° parabolically distributed. The aircraft trimmed with elevons neutral at 280 k.p.h. ($C_L = 0.16$).

Performance

The following performance data were quoted by Reimar Horten from memory:-

Flying weight (minimum)	2,900 kg
" " with full equipment	3,200 kg
Engines	2 × 240 H.P. Argus AS 10 C (normally aspirated) with constant speed propellers.

Sea level	Cruising speed (180 - 200 H.P. per engine)	310 k.p.h.
	Top speed	340 k.p.h.

Normal take-off speed	110 k.p.h.
Ground run	250 metres
Sea level rate of climb at 180 k.p.h. (full power)	7 metres/sec.
Ceiling	6,500 metres

C_L max = 1.2 no flaps

= 1.6 with all flaps ΔC_L due to plain flap was 0.1.

Handling characteristics.

Reimar Horten told us that prior to the first flights by Scheidhauer on the H VII, his brother Walter had supervised the C.G.'ing of the aircraft and mistakenly put ballast in the nose because the measurements were made with a steel tape with 10 cm. missing from the end. Scheidhauer's comments to us were that the aircraft had to be brought in at a minimum speed of 120 k.p.h., with the stick nearly right back, if the nose was to be lifted for the hold off; the aircraft then floated (stick fully back) until 90 k.p.h. before touching down. Normal take-off procedure was to accelerate to 120 k.p.h. and then pull the stick back when the aircraft immediately took off and climbed away. Apparently it could be unstuck at 90 k.p.h. by pulling back hard but would not climb until 120 k.p.h. had been reached. It was impossible to stall the aircraft with the C.G. in this position; the general behaviour was said to be "good natured".

Walter flew the H VII (with the C.G. in its correct position) on 30 - 40 occasions, a total flying time of about 18 hours. (Scheidhauers time was also about 18 hours). Apparently the change in C.G. brought the approach speed down to about 100 k.p.h. and the aircraft could be touched down on the rear wheels. It was not certain that a complete stall could be produced in steady flight. With the stick fully back the aircraft sank on an even keel with fair lateral control. Lateral control was pleasant, the 25% Frise balance eliminated adverse yaw and virtually enabled flying on two controls.

Tests with the "trafficator" drag rudder showed that single engined flight could be maintained with half rudder and a little sideslip; turns could be made in level flight against the dead engine. On one test the pilot was carrying out a single engine approach when he realised that he had stopped the engine supplying the undercarriage hydraulics and could not lower the wheels. He was able to climb away, start the dead engine and make a normal landing.

3.10 Horten V III

General

This was to have been a flying model of a proposed six engined trans Atlantic passenger transport weighing 100,000 kg. The span was to be 40 m. with an aspect ratio of 10 and sweepback of 28°. Power units were six Argus AS 10 C engines.

To make the aircraft attractive to R.L.M. and thus get backing for the project, the Hortens added a rear loading cargo carrying body with an internal space approximately 14' × 10' × 6' ; this was not part of the design for the full size aircraft. With construction under way, another modification was made (but not disclosed to R.L.M). This consisted of removing the nose of the cargo body, replacing the nose wheel by wheels on either side of the body and putting a large venturi tube with a 2m × 2.7 m throat inside to form a flying wind tunnel. They expected to get about 500 m.p.h. airspeed in the throat combined with low turbulence - this they proposed to check by the sphere drag method. Later they hoped to be able to test models of their aircraft which could be made of wood because of the absence of dust in the airstream.

Construction was proceeding at Göttingen and was 50% complete at the cessation of hostilities. The steel tube framework for the venturi centre section was finished.

Estimated weight and performance figures

Max. all up weight as a wind tunnel	- 9000 kg.
" " " " " cargo carrier	
Without take-off assistance	- 15,000 kg.
Ditto with rocket assisted take-off	- 20,000 kg.

At 23,000 kg. the sea level rate of climb at full power would be zero.
At 9,000 kg. rate of climb at 180 k.p.h. was expected to be $6\frac{1}{2}$ - 7 m/s.

Estimated trimmed C_L max's were

No flaps	1.4
With flaps	1.6
C_L for take-off	1.1

Aerodynamic design

The design of the wing and controls was similar to that of the Horten IV. Washout was large, 7°, to give trim without elevator deflection at cruising C_L. Elevons were the three stage type with 35% Frise nose on the outer flap, and 22% on the middle and inner flaps. Compensating geared tabs which could also be used as longitudinal trimmers were fitted to the inner flaps. Maximum control deflections were as follows:-

Case	Port			Starboard		
	Outer	Centre	Inner	Inner	Centre	Outer
Stick fwd. and central	+ 5°	+ 12°	+ 15°	+ 15°	+12°	+ 5°
back and central	-10°	- 18°	-10° or -15°	-10° or -15°	-18°	-10°
Central and to port	-30°	- 15°	- 8°	+ 12°	+10°	+ 5°
Central and to stbd	+ 5°	+ 10°	+12°	- 8°	-15°	-30°

Trailing edge split flaps with a constant chord of 80 cm. were to be fitted between the engines.

Drag rudders were of the H VII "trafficator" type with vent hole balance plus spring centering. Projection was about 1 metre.

Wing sections are shown in Fig. 18. Root thickness is about 16%, with the usual reflexed centre-line, graded to an 8% symmetrical tip section.

Structure

Wing structure was in seven parts; a welded steel centre section with pilot and co pilots seat and three outer wooden wing panels per side. The wooden structure was of single spar D-nose form with subsidiary trailing edge ribs.

At the factory in Göttingen the centre section was found in a semi complete state, D-noses for the inboard wing panels were finished and spars and ply noses for the outer panels were under construction. Much of the work on components such as engine bearers, petrol systems, undercarriages etc. had been completed and the 6 engines were in crates at the works, with one spare. Unfortunately all drawings had been taken and many of them seem to have been buried by Horten employees near Eilenburg, in the Russian sector.

Undercarriage

The fixed main wheels were arranged in tandem pairs on either side of the fuselage and took 85% of the static weight of the aircraft. The castoring nose wheel was retractable on the cargo version and had to be mounted on a stalky strut because of the high wing layout. Static ground incidence was $2\frac{1}{2}$°.

3.11 Horten IX

General

The H IX was a single seat fighter bomber of 16 m span with twin jet engines, being a further development of the HV & H VII designs. Fig. 19 is a general arrangement drawing made from a wooden model found at Göttingen, where the first two of the type were built.

Four aircraft of H IX type were started, designated V.1 to V 4. V.1 was the prototype, designed as a single seater with twin B.M.W. 003 jets, which were not ready when the airframe was finished. It was accordingly completed as a glider (Fig.20) and extensively test flown. D.V.L. instrumented it for special directional damping tests to determine its suitability as a gun platform. V2 was completed (also at Göttingen) with two Jumo 004 units and did 2 hours flying before crashing during a single engine landing. The pilot (Ziller) apparently landed short after misjudging his approach. V3 was being built by Gotha at Friedrichsroda as a prototype of the series production version. V4 did not get beyond the project stage but was to be a two seater night fighter with an extended nose to house the extra man (Fig.19).

In shape, the H IX was a pure wing with increased chord at the centre to give sufficient thickness to house the pilot and the jet units, which were placed close together on either side.

Aerodynamic design

The H IX started as a private venture and the Hortens were very anxious to avoid failure so they avoided aerodynamic experiments wherever possible. A lower sweepback was used than on the H V and H VII and laminar flow wing sections were avoided as a potential source of trouble. Wing section at the junction with the centre section was 14% thick with max. thickness at 30% and 1.8% zero C_{m_0} camber line. At the centre line thickness was increased locally to 16% to house the crew. The tip section was symmetrical and 8% thick. Horton also believed that since the compressibility cosine correction to drag was based on the sweepback of the max. thickness line, the ordinary section would show little disadvantage.

Wing twist was fixed by consideration of the critical Mach Number of the underside of the tip section at top speed. This gave a maximum washout of 1.8°. Having fixed this, the C.G. was located to give trim at $C_L = 0.3$ with elevons neutral. In deciding twist for high speed aircraft, C_D values were considered in relation to local C_L at operational top speed and altitude (10 km. in the case of the H IX). Twist was arranged to give minimum overall drag consistent with trim requirements. The wing planform was designed to give a stall commencing at 0.3 to 0.4 of the semi-span.

Structure

Wing structure comprised a main spar and one auxiliary spar of wooden construction with ply covering. The centre section was built up from welded steel tube. Wing tips were of metal. The undercarriage was completely retractable and of tricycle type the front wheel folding backwards and the main wheels inwards. The nose wheel was castoring and centred with a roller cam. When resting on the ground, wing incidence was 7° and the nosewheel took about 40% of the total weight.

Engine installation

The jet engines were installed at -2° to the root chord and exhausted on the upper surface of the wing at 70%C back from the nose (Fig.22). To protect the wings the surface was covered with metal plates aft of the jet pipe and cold air bled from the lower surface of the wing by a forward facing duct and introduced between the jet and the wing surface. The installation angle was such that in high speed flight the jets were parallel to the direction of flight.

All fuel tanks were in the wings.

Control system

Lateral and longitudinal control was by single stage elevon control flap with 25% Frise nose and compensating geared tab balance. (This system was also used on the H VII see para. 4.6). The pilots control column was fitted with a variable hinge point gadget, and by shifting the whole stick up about 2 inches the mechanical advantage could be doubled on the elevons for high speed flight.

Directional control was by drag rudders. These were in two sections, slight movements of the rudder bar opening the small (outboard) section and giving sufficient control for high speed. At low speeds when coarser control was necessary the larger movements also opened the second spoiler, which started moving when the small one was fully open. By pressing both feet at once, both sets of spoilers could be operated simultaneously; this was stated to be a good method of steadying the aircraft on a target when aiming guns. The Hortens stated that the spoilers caused no buffeting and claimed an operating force of 1 kg for full rudder, with very little variation with speed. The operating mechanism is illustrated in Fig. 28. A change was made from the original H VII parallel link system to improve the control force characteristics. With the new system, aerodynamic forces could be closely balanced by correct venting of the spoiler web, leading the main control load to be supplied by a spring. The cover plate of the spoilers was spring loaded (Fig. 27) to form an effective seal with the rudders closed; this device was used on most Horten spoiler and dive brake designs.

On further models of the H IX it was proposed to fit the "trafficator" type rudder tried experimentally on the H VII.

Landing flaps consisted of plain trailing edge flaps (in four sections) on the wings, with a 3% chord lower surface spoiler running right across the centre section which functioned as a glide path control. The outer pair of plain flaps lowered 27° and the inner pair 30° - 35° on the glider version V.1. On V 2 mechanical troubles prevented the inner pair operating and all flying was done with the outer pair only. The centre section spoiler could be used as a high speed brake and gave 1/3 g at 950 k.p.h. No dive recovery flap was considered necessary.

Performance

Proper performance tests were not done on V 2 before its crash and top speed figures were calculated values, checked by Messerschmitts. The following figures were remembered by Reimar Horten:-

Dimensions:-

All up weight, including ammunition & armour	8,500 kg (18,700 lb.)
" " excluding " " "	7,500 kg
Wing area	52 sq. m (566 sq.ft)
Wing loading	33 lb/sq.ft.
Fuel (I2 crude oil)	2,000 kg. (4,400 lb.)

Performance at 7,500 kg (16,500 lb.)

Take-off run	500 m
Take-off speed (10° flap)	150 km/hr. (93 m.p.h.)

(Note: This corresponds to a C_L of 1.30 which is the stated stalling C_L of the aircraft).

Top speed	950 k.p.h. (590 m.p.h. at sea level

(C_{D_0} estimated to be 0.011)

Calculated ceiling was 16 km (52,000 ft.) Engines would not work above 12 km. as the burners went out.

Rate of climb at S.L.	22 m/s (4300 ft/min)

(Note: this has been checked roughly by observation).

In tests against the Me 262 speeds of 650-700 km/hr (400-430 m.p.h.) were obtained on about 2/3 throttle opening. This appears to be the only flight test figure available.

Messerschmitt sent performance calculators to the Horten works to check their estimates. The method suggested by D.V.L. for getting the sweepback correction to compressibility drag was to take an area of 0.3 × the root chordsquared at the centre section as having no correction applied, and then apply full cosine correction over the outer wing. Sweepback angle was defined as that of the quarter chord locus. Test data was available for C_D v. M for zero sweepback.

The Messerschmitt method was to base sweepback on the max t/c locus and to scale Mach number by $\sqrt{\cos \phi}$.

Stability and control

The H IX V 1 was flown by Walter Horten, Scheidhauer and Ziller. Scheidhauer did most of the flying (30 hours) at Oranienberg, Horten and Ziller flew for about 10 hours.

D.V.L. instrumented the aircraft for drag and directional stability measurements. No drag results were obtained because of trouble with the instrument installation - apparently an incidence measuring pole was fitted which could be lowered in flight and glide path angle was obtained from the difference between attitude and incidence measurements. One day they landed without retracting the pole. Directional oscillation tests were completed successfully and an advance report was issued (10 pages of typescript) by Pinsker and Lugner of D.V.L.

The essence of the results was that the lateral oscillation was of abnormally long period - about 8 secs. at 250 k.p.h. and damped out in about 5 cycles. At low speeds the oscillation was of "dutch roll" type but at high speed very little banking occurred. Many fierce arguments took place at D.V.L. on desirable directional stability characteristics, the Hortens naturally joining the "long period" school of thought. They claimed that the long period would enable the pilot to damp out any directional swing with rudder and keep perfectly steady for shooting. It was found that by using both drag rudders simultaneously when aiming, the aircraft could be kept very steady with high damping of any residual oscillation.

Lateral control was apparently quite good with very little adverse yaw.

Longitudinal control and stability was more like a conventional aircraft than any of the preceding Horten types and there was complete absence of the Longitudinal "wiggle" usually produced by flying through a gust. Tuft tests were done to check the stall but the photographs were not good enough for much to be learned. Handling was said to be good at the stall, the aircraft sinking on an even keel. There seems to be some doubt, however, as to whether a full stall had ever taken place since full tests with varying C.G. and yaw had not been done. Although the stick was pulled hard back, the C.G. may have been too far forward to give a genuine stall.

Directional stability was said by Scheidhauer to be very good, as good as a normal aircraft. We did not discuss this statement in detail as he was obviously very hazy about what he meant by good stability and could give very little precise information about the type and period of the motion compared with normal aircraft.

Scheidhauer had flown the Me 163A as a glider and was obviously very impressed with it; he was confident enough to do rolls and loops on his first flight. We asked him how the H IX V.1 compared with the 163; he was reluctant to give an answer and said the two were not comparable because of the difference in size. He finally admitted that he preferred the 163 which was more manoeuvrable, and a delight to fly (he called it a "spielzeug").

The H IX V.2 with jet engines, was flown only by Ziller and completed about 2 hours flying before its crash. This occurred after an engine failure - the pilot undershot, tried to stretch the glide and stalled. One wing must have dropped, for the aircraft went in sideways and Ziller was killed. Before the crash a demonstration had been given against an Me 262; Horten said the H IX proved faster and more manoeuvrable, with a steeper and faster climb.

In spite of the crash Horten thought the single engine performance satisfactory and said the close spacing of the jets made single engined flying relatively simple.

3.12 Horten X

The H X was a high speed arrow shaped flying wing (Fig. 20) inspired by Busemanns statement in 1936 of the beneficial effect of sweepback on delay of the shock stall. This apparently cheered up the Horten Brothers and gave them new proof that they were working on the right lines.

Initial work on the H X consisted of experiments with flying models of 10 ft. length weighing about 8-10 kg. From these they deduced the C.G. position needed for satisfactory flight with low aspect ratio and high sweepback, and found that they got good results with 4° dihedral and no fin area.

The next step was a man carrying glider model weighing 400 kg, with the overall dimensions of Fig. 25. The wing section was a symmetrical D.V.L. low drag type with maximum thickness at 45% C. Wing washout was $1\frac{1}{2}^{\circ}$, dihedral 4°; Small Frise nose elevons were fitted but no flaps; a trimmed C_L max of 0.8 was expected with a stalling incidence of 20° - 25°. Rudder control was to be by wing tip "trafficators". The undercarriage was of tricycle layout giving zero ground incidence but clearance for a 15° nose up attitude at take-off; the front wheel was to be retractable but the rear wheels fixed.

Work on the glider H X was in progress at Hersfeld. When the writer visited the works on June 4th 1945 it was being used as an M.T. servicing depot and all aircraft components had been dumped in a basement. Only one wing rib and the main spar could be found. All drawings and calculations had gone.

After an exploration of low speed control problems on the glider, the next step was to have been a power version with an Argus AS 10 C pusher engine. The final development was envisaged as a jet propelled aircraft, with the same general dimensions, weighing 6 - 7,000 kg. A single H 11 jet engine was proposed and a top speed of 1200 k.p.h. was expected with 1300 kg. thrust ; the thrust was to be improved to 1500 kg.

Initial tests on control effectiveness with high sweep were carried out on the H XIII to guide the control design for the H X. No ideas for controls on the final version had emerged but Horten said he intended to stick to Frise nose balance as long as it would work.

In general appearance the H X bears a resemblance to the Lippisch designs for high speed and supersonic aircraft, particularly the P 13. Horten said he had not heard of Lippisch's work in Vienna until he came to London. The main difference in design is that Hortens think a fin unnecessary whereas Lippisch favours a very large one.

3.13 Horten XI

This was an aerobatic sailplane of 8 meters span. It was built at Hersfeld and had no features of special interest.

3.14 Horten XII

The H XII was a light side by side two seater with a 100 H.P. engine. It was intended as a private owners coupé but R.L.M. were interested in it as a trainer. The first of the type was built and flown at Göttingen (where it was found destroyed in June this year) as a glider; work was also in progress at Kirtorf where a mock up of the power centre section was found, badly damaged by fire.

General dimensions were as follows:

Span	16 metres
Aspect Ratio	8 "
Wing area	32 sq. metres (345 sq.ft)
Leading edge Sweepback	30°
Weight	700 kg (1550 lb)
Wing loading	2.19 kg/sq.in. (4.5 lb/sq.ft)

The wing used a Mustang section at the root graded to a symmetrical section with Mustang fairing shape at the tip. Washout was $3^\circ - 3\frac{1}{2}^\circ$.

Elevon controls were of H VII type with a 20% Frise nose. Plain flaps were fitted with an H IX centre section spoiler and "trafficator" drag rudders.

The undercarriage was unusual in having two wheels forward and one main wheel aft taking 60 % of the weight. All three wheels were retractable.

Little flying had been done, but it was found that the same troubles were arising as on the IVb. The laminar flow sections were causing bad tip stalling and loss of control effectiveness at the stall.

3.15 Horten XIII

As part of their programme on high sweepback, the Hortens built the H XIII for a quick experiment, to give flight test results on control problems. The glider consisted of H III wings, fitted to a new centre section giving a leading edge sweep of 60°. This increase of sweep reduced the aspect ratio to four. Control deflections were all doubled to compensate for the obliquity of the hinge line and the ends of the control flaps trimmed to run parallel to the new aircraft centre line.

The pilot had to be carried in an underslung nacelle to give him a reasonable view; the control column was inverted and hung from the roof of the nacelle.

Undercarriage consisted of a main wheel inset in the nacelle and a fixed nosewheel mounted on a welded steel tube fork (Fig.24).

Flying on the H XIII totalled about 10 hrs. Trials were interrupted in the middle by Scheidhauer landing in a barbed wire fence.

C_L max was found to be 0.9, with the stick right back. In this condition the incidence was larger than expected - about 20° - 25° instead of 15°, but Horten thought that the induced drag was not correspondingly increased. It was thought that the wing was not completely stalled with the stick hard back because the C.G. was too far forward.

Control was moderately satisfactory, but in spite of the increased elevon travel was inclined to be sluggish. Elevator control particularly was much less sensitive than on other Horten aircraft.

3.16 Horten XIV

This was a sports sailplane designed to conform to the 1939 Olympic Games specification. It was designed for simplicity and ease of production. The first aircraft was built from sketches and proper drawings for the production type were made later with slight modifications. Construction was carried out at Hersfeld.

Span was 15 m and aspect ratio 16.2 The wing had 20° leading edge sweep and 8.6° total twist. Sections were 4% camber 17% thickness at the root with 10% thick symmetrical tips. Empty weight was 120 kg giving a flying weight of 220 kg.

Controls consisted of one Frise nose elevon per side with rudders and dive brakes of H IV design. The glider trimmed at $C_L = 1.0$ with elevons neutral.

The pilot was put in a prone position, as on the IV and the undercarriage arrangement was also similar but for the replacement of the rear skid by a wheel.

Performance was stated to be

Max. gliding ratio 1 : 30 at 70 k.p.h.
Min. sinking speed 0.62 m/sec at 55 k.p.h.

3.17 Horten parabola

According to Reimar Horten this planform is theoretically the most efficient and has the minimum induced drag. The validity of the theory is not known. The glider was constructed in a burst of enthusiasm but proved rather awkward to make because of its curves and was damaged during transport and never flown.

3.18 Projected jet bomber

In February 1945 a committee under Prof. Bock with representatives from Junkers, Messerschmitt and Horten, deliberated over the optimum design for a 4 jet engined bomber. Designs by Junkers (Ju 287, a swept forward tailed aircraft) Messerschmitt (Project 1107 a swept back tailed aircraft) and Horten (swept back tailless) were considered, and a joint report issued giving the committee's opinion on the best estimate for relative performance. Junkers published the report.

The specification to be met was for 900 k.p.h. at 10 km height and a range of 3000 km using four H 11 jets. According to Horten the committee decided that his machine, given the same top speed as the others would have more range and less landing speed. (125 k.p.h. against 175 k.p.h. for the others). Alternatively he could carry 8 tons (metric) of bombs against 4 by his competitors for the same range.

The dimensions of the aircraft were roughly as follows:-

	Ju and Me	Horten
Span	17-18 m	30 m
Aspect Ratio	$5\frac{1}{2}$	$5\frac{1}{2}$
Wing loading	500-600 kg/in^2	220 kg/in^2

Horten said the agreed C_{D_o} for this aircraft was 0.0078 excluding Mach No. correction.

In the structural design he reckoned to save 6% of the all up weight (spar and rib weight) compared with a conventional type. He thought the committee a bit unfair because they insisted on increasing his estimate of structure weight by about a ton.

All the above figures were remembered by Horten, who used them as a rough illustration. They are not accurate.

4 How the Hortens design their aircraft

Introduction

The Hortens started their careers as aircraft designers in a very practical way, without assistance from highbrow theory. Early designs were based mainly on what they found satisfactory on a small scale model. As time went on Reimar Horten began theoretical investigations of various problems that took his fancy and built up a fairly complex basic design procedure. Some of his methods seem strange to us and some important aspects he still leaves to "experience" where we tend to trust theory. The following is a brief account of his methods as related to us at Göttingen in September 1945.

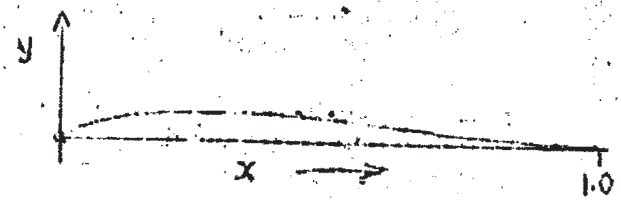
4.1 Wing section design

Wing sections were designed from scratch and were never wind tunnel tested. The only exception to this rule was the disastrous adoption of the Mustang profile for the H IVb and the H XII.

Camber lines were designed by Birnbaum's thin aerofoil theory to give zero C_{m_o}. This gives an equation for the case of 3% maximum camber :-

$$y = \frac{0.03}{0.1055}\, x\,(1 - x)^3$$

This has $\frac{dy}{dx}$ and $\frac{d^2y}{dx^2}$ both zero at $x = 1$ and gives $y = \max$ at $x = 0.25$



For fairing shapes they used half the lemniscate

$$y = \frac{t}{c}\sqrt{x}\,(1 - x)\sqrt{2 - x}$$

giving max $\frac{t}{c}$ at $\frac{x}{c} = 30\%$.

For fairing shapes with maximum thickness at 40% they used a geometrical projection method due to Ringleb.

To get good stalling characteristics the following criterion was used:

$$\frac{\rho/c}{(t/c)^2} \underline{\Omega}\ 1.0$$

where ρ = nose radius

c = chord

t = max. thickness

This criterion is well known and a report by Kawalki of D.V.L. has been published on the subject.

Wing tip sections are made symmetrical because Horten dislikes the idea of a cambered section with negative flap deflection at the stall.

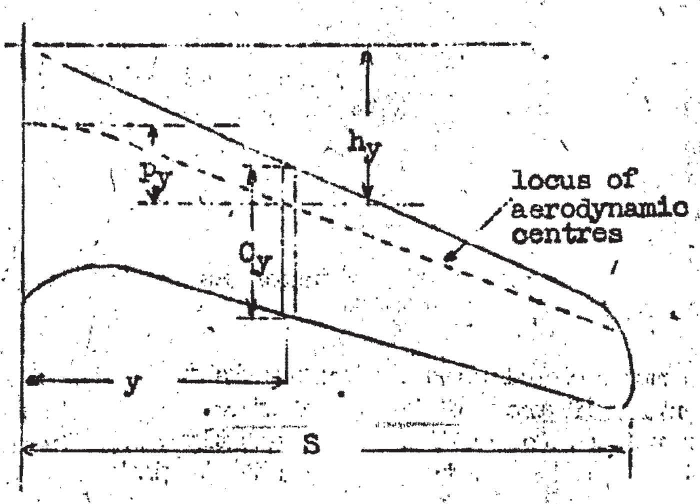
Horten thought that position of the maximum thickness of the wing section had a definite influence on the sweepback that could be used (and vice-versa) due to the influence on lateral flow in the boundary layer. He suggested the following rough rule for 12% thick sections

Max thickness location	Maximum sweep (Leading edge)
30%	45°
40%	35°
50%	20°

This rule was based on his experience of the flying qualities of aircraft so far built.

4.2 Calculation of aerodynamic centres

Aerodynamic centre was calculated by integration of the product of local loading × distance of the local aerodynamic centre behind a convenient spanwise datum. Load distribution was first calculated by Weissingers method for a swept back wing. Details of this were not known but it was apparently a development of Multhopp's method which extended the lifting line theory to take account of chordwise pressure distribution and the influence of this on induced velocity along the span. Load distribution was used to give values of $\frac{d\,C_L}{d\alpha}$ local wing.



Local aerodynamic centre was assumed to be at 0.25 × η × C from the leading edge η being a factor representing the departure of the two dimensional lift curve slope from 2π. η had approximately the following values for different thickness ratios:-

t/c	η
0%	0.91
10%	0.89
20%	0.85

$$\eta = \frac{dC_L/d\alpha}{2\pi} \text{ (for section in two dimensions).}$$

The neutral point h_n was then given by

$$h_n = \frac{\int_0^s \frac{dC_{Ly}}{d\alpha} \cdot C_y \cdot h_y \, dy}{\int_0^s \frac{dC_{Ly}}{d\alpha} C_y \, dy}$$

Centre of gravity positions were specified by Horten as distances ahead of the above neutral point in terms of a dimension called the "Pfeilmass". The Pfeilmass is a measure of the fore and aft dimension of the wing and is defined by

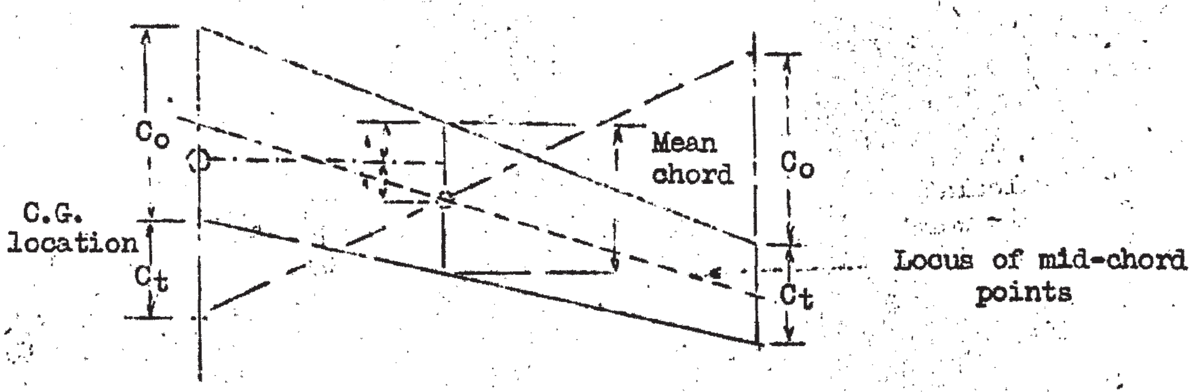
$$P = \frac{\int_0^s p_y \, dy}{s}$$

p_y is the fore and aft distance between the aerodynamic centre of the centre section and the aerodynamic centre at the general point y.

4.3 Fixing the layout

Preliminary determination of C.G. position

As a first approximation Horten used the following graphical construction to give a mean chord and mean quarter chord point.

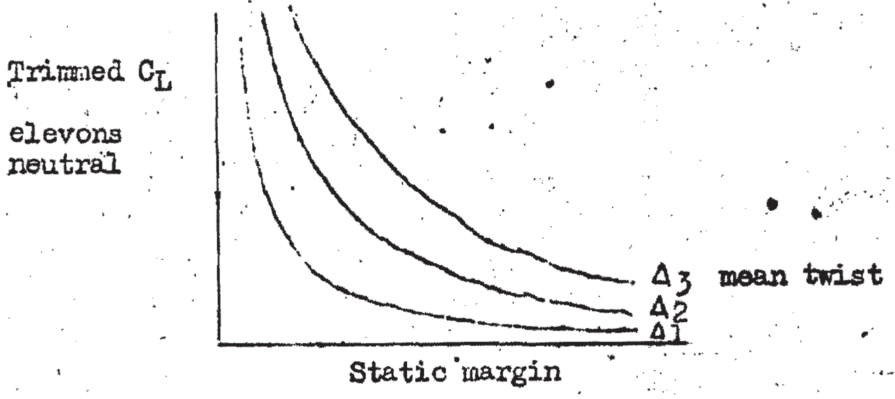


The first approximation to the C.G. position was taken as the mean quarter chord point defined as above.

It will be noticed that the mean chord used by Horten is the local chord line passing through the centre of area of the half wing. The above construction does not apply to planforms differing greatly from a trapezium. The chord length so defined is not the same as that given by $\frac{S}{b}$.

Wing twist

The procedure here was to construct curves from which static margin could be chosen if wing twist had been decided, or, more usually, to choose twist for a given static margin, assuming in either case that the desired C_L with elevons neutral was known.



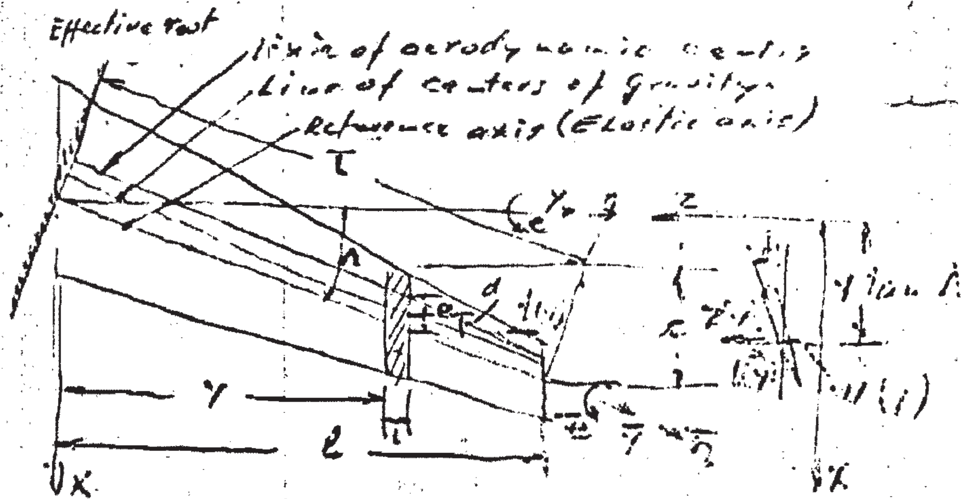
Mean twist was defined as

$$\Delta = \frac{\int_{-s}^{+s} \Delta_y C_y \, dy}{S}$$

where

C_l = local lift coefficient on streamwise segment

m = mass per unit length along the y axis


Effective root
Line of aerodynamic centers
Line of centers of gravity
Reference axis (Elastic axis)
T
Λ
d
e
y
l
X
z

Slender swept wing
with streamwise segments.

Swept back wings possess an infinite divergence speed.
(freedom only in bending)

The bending and torsional stiffnesses are assumed to vary as the fourth power of the chord. (on page 48)
math. formulas ...

S. MARTON.

Where Δ = mean twist

Δ_y = twist at general point y

C_y = chord " " " "

S = wing area

s = semi span

Desirable static margins were known from experience and Horten gave the following table (all in % of Pfeilmass) of values for different Horten aircraft.

Type	Static margin (% p)	Comments
II	5%	
III	4%	Normal position
	2%	Minimum for satisfactory longitudinal stability
	5%	For best longitudinal characteristics
	3%	For optimum performance
IV	5%	Normal
	6 - 7%	Best handling
V, VII, IX	2 - 3%	

On sailplanes, twist was designed to give elevon neutral trim near to the C_L for best gliding angle and on power aircraft trim at cruising C_L. Centre section head fairings were found to have an appreciable effect on trim.

In the case of high speed aircraft, selection of mean twist was further complicated by the need to avoid local shock stall at high speed. The method of dealing with this was described in para. 3.11 under "Aerodynamic Design".

Twist distribution was determined by the type of aircraft. For a sailplane, which spends much of its time in circling flight, Horten had developed a theory which enabled twist distribution to be designed so that the glider was in trim laterally and directionally without elevon or rudder deflection. In the calculation the twist needed to give static equilibrium was found, taking into account variation of incidence, speed, profile and induced drag across the span and assuming straight trailing vortices.

The answer was a twist of the form

$$\theta = \theta_0 \left(A \frac{y}{s} + B \left(\frac{y}{s}\right)^3 \right)$$

the second power term being indeterminate.

On the H IV for example, twist was designed to give trim in a 45° banked turn at $C_L = 1$. Incidence difference between the tips was 1° and the twist was

$$\theta = 2^\circ \left(\frac{y}{s} + \left(\frac{y}{s}\right)^2 + \left(\frac{y}{s}\right)^3\right)$$

An additional aerodynamic twist of 1.1° was added giving an overall designed washout of 7.1°. The second power term was introduced to satisfy the condition for longitudinal trim (flaps neutral for trimmed flight at 100 k.p.h. on the IV and 140 k.p.h. on the VI).

On the H III the linear term was much bigger (4°) and the incidence difference between the tips 6° in the specified circling condition.

Torsional deflection of the wing was allowed for in these calculations.

In addition to the above requirements Horten also designs the combination of taper and twist to ensure that local stalling lift coefficient is first reached at the middle third of the semi span. Apparently all these conditions can be satisfied simultaneously, the linear term was said to be available mainly for stall control whilst the cubic term gave the required rolling equilibrium.

Sweepback

Sweepback is governed to some extent by the load being carried, but for low speed aircraft Horten liked to keep leading edge sweepback below 45° to avoid loss of controller power through boundary layer outflow. For high speed aircraft, high sweepback was an advantage, for besides keeping drag down it prevented over sensitivity of control.

4.4 Control design

No calculations of control forces were customary, design was governed by experience. Aileron performance was however calculated on the H IX.

The change over from round nosed to Frise nosed controls was made to improve the yawing characteristics with aileron application. The subdivision of the flap into two parts enabled differential to be used to improve the favourable yaw with aileron. The outer Frise nose in this case balanced the round nosed inner flap also. In the three stage flap, where the outer flap behaved principally as up going aileron, it was possible to alter the relative balance between aileron and elevator (the latter being usually too light relative to the aileron) and produce better harmony of control. This was said to be especially important in high aspect ratio sailplanes (or aeroplanes like the H VIII) where the ratio of lateral inertia to longitudinal inertia is high (e.g. this ratio was about 30 on the H IV compared with 5 on the H IX). Further questioning revealed that Horten thought lateral inertia important because the initial response (acceleration) when correcting small gust disturbances depended largely on inertia although the final rate of roll was hardly affected.

Drag rudder design was evolved entirely by flight experiment with no wind tunnel data to help.

4.5 Flight stability

Dynamic stability was never investigated theoretically and was not studied very carefully in flight. Reliance was placed mainly on general impressions of the pilot and we found no evidence of results having been analysed critically.

The Hortens were obviously not in the habit of thinking in terms of periods and dampings, and Reimar did not know what l_v and n_v were for his various designs; dihedral was fixed by experience.

The "stick force per g" criterion was not used and although elevator angles to trim were considered in the design stage there was no methodical flight check.

4.6 Undercarriage design

During the construction of their series of aircraft the Hortens had been forced to try a number of unorthodox undercarriage layouts using 2,3 and 4 wheels. The tricycle and four wheel layouts used wheel positions giving a wide range of weight distribution. The following figures were quoted:-

Type	H IV	H V	H VIII
Nose wheel reaction (% A.U.W.)	8	55	15
Mainwheel "	92	45	85

The H VII and H IX also take a large proportion of the weight on the nosewheel - of the order 40 - 50%. These heavy nosewheel reactions were combined with large ground incidences to enable the aircraft to fly off the ground.

According to Horten none of the layouts tested had given any trouble due to porpoising or inability to unstick; he was inclined to dismiss undercarriage design as presenting no problems.

4.7 Stressing

Horten stated that there were no special requirements for stress calculations on tailless aircraft. The H IX was designed for a normal acceleration (n) of 7g combined with a safety factor (j) of 1.8. Other design considerations were as follows:-

(a) Gusts of ± 10m/sec. in a dive at 1100 k.p.h. with j = 1.2. The air was assumed incompressible for this calculation except that $dC_L/d\alpha$ was arbitrarily increased 50% over the incompressible value. A relieving factor of 0.6 was applied.

(b) A complete aileron roll (360°) was to be possible at 900 k.p.h. at 2500 m. in 4 seconds, including allowance for aero elastic distortion. This was both a performance and a stressing requirement.

(c) There were no official aileron reversal requirements but Hortens designed the H IX for a reversal speed of 1.2 × diving speed (1320 k.p.h.) assuming incompressible flow.

A peculiar feature in the structural design of the VII was mentioned. It was stated that the calculated change of trim to cause a 4g dive pull out at diving speed was only 0.3° of elevon, when allowance was made for aero elastic distortion. This was improved by increasing the ply skin thickness from 1.5 mm to 2.5 mm. The phenomenon would be more understandable if the torsion component of spar bending had been large but Horten says that this was not included.

Actual figures quoted were:-

	Elevator angle	
	1.5 mm ply	2.5 mm ply
Dive	+ 3°	+ 2.5°
4g pullout	+ 2.7°	- 0.5°

5 Comments on some aerodynamic aspects of the Horten designs

5.1 Stability and control in unstalled flight

Longitudinal

This seems generally to have been satisfactory. It is clear that, particularly on their light aircraft, there was a difference in longitudinal gust response (and probably also in control response) which seems to have been more sudden than on a conventional type but this was less marked in the H IX which had more normal wing loading. The Horten view was that with correct C.G. positions there was little important difference. When questioned about static stick free instability when approaching the stall they thought it might possibly be present but were sure that stick force reversal did not occur.

On the H IV a peculiar form of longitudinal instability was mentioned by Reimar Horten. Apparently a short period oscillation (period about 1 sec.) would be produced with damping varying with speed, being about zero at 180 k.p.h. At higher speeds it showed signs of building up spontaneously (-ve damping). A theory was that it might be due to a coupling with flexure and torsion of the wing but no proof had been obtained.

Lateral

All their aircraft appear to have had less damping of the lateral oscillation than normal but also a longer period which made it easier for the pilot to damp out disturbances with rudder. This feature is of interest in view of the widely held view in Germany that the period of the lateral oscillation on a high speed fighter (particularly jet propelled) is too short for good gunnery and should be increased if possible to 4 secs.

Directional

Directional stability would be expected to be indifferent because of the absence of fins. Northrop has found on his aircraft that the low values of n_v and y_v made it possible to fly with appreciable yaw without the pilot knowing it, and this led to unpleasant characteristics in rough air. Horten is satisfied with the behaviour of his aircraft without fins and Stüper could not find anything to criticise in this direction on the H V. At R.A.E., after about 1 hour's flying on the

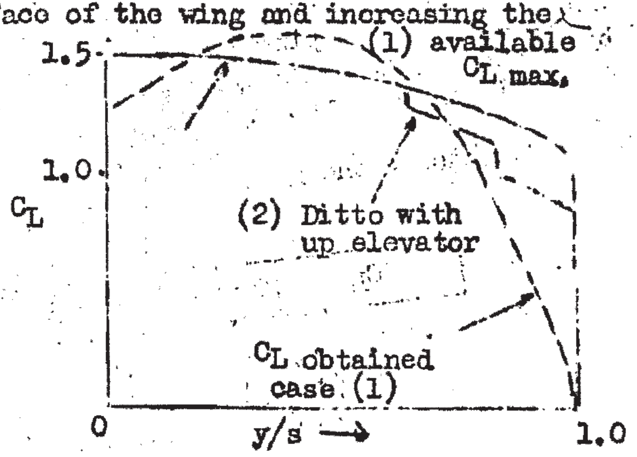
H IV, the impression is that there is definitely something unusual in directional stability and control. It seems possible to fly with considerable yaw and the response to drag rudder is quite different from that of the conventional aircraft to a normal rudder. As yet it is too early to give a full report on these features.

5.2 Behaviour at the stall and recovery from the spin

Stall research

Besides doing normal stall tests, Horten did a certain amount of research with wool tufts to gain insight into the flow changes at the stall. On the H II glider surface tufts were used and photographed by a camera in the pilots head fairing. On the H III more extensive tests were done using surface tufts on one wing and tufts on 2" masts on the other, the stall being photographed from a Storch flying immediately above. To assist in the interpretation of the photographs the glider was fitted with a sideslip vane and an A.S.I. which registered on the upper surface of the wing and appeared in the pictures. Chordwise lines were painted on the wing to show readily any yaw of the tufts. This technique proved difficult, particularly for the Storch pilot, and the photographs were apparently not very good. They did confirm however that the stall started at the middle of the semi span, and showed the spanwise drift of the boundary layer. The H V and H IX were also tufted but no pictures were taken. Horten said that the tufts again showed that the wing tips did not stall and in the case of the H V the stall was sketched as spreading to the root whilst leaving the outer 30% of the semi span unstalled.

In general, Horten thought that a stall with C.G. back would be worst because the upward elevon angle would be reduced, producing reduced pressure on the upper surface of the wing and increasing the spanwise flow.



The picture of designed and available C_L distribution was as shown. This actually gives slightly better results with C.G. aft, for, if the extra up elevon required for trim with C.G. forward decreases the available tip C_L max by ΔC_L, then the obtained C_L at the tip decreased only by $0.9C_L$. However the spanwise flow effect was thought by Horten to be of overriding importance.

Tests on the influence of C.G. position on flying characteristics

Tests on the stalling and spinning of an H III glider were done at the Hornberg with varying C.G. position. To start with, weight was added at the back of the centre section until the glider was only just flyable. This required 35 kg of ballast (the normal C.G. position was 2.1 metres behind the centre section leading edge, corresponding to 4% pfeilmass static margin). A tube 2 m. long was then put under the centre section with a 10 kg sliding weight which was kept forward for take off and landing and moved aft for tests at height, giving a static margin of 0 to $-\frac{1}{2}$% pfeilmass.

Flight characteristics were as follows:-

(a) C.G. forward (10% pfeilmass ahead of neutral point). Stalling and spinning were impossible.

(b) C.G. normal (4% of pfeilmass ahead of neutral point). Stalling was possible but spinning difficult. Spinning attitude was steep and normal recovery procedure resulted in a steep dive with little sideslip.

(c) C.G. aft (2% pfeilmass).

Normal flying characteristics began to be unpleasant. Longitudinal control became very touchy.

(d) Extreme aft C.G. (0 to -½% pfeilmass)

With this C.G. position it was only just possible to fly the aircraft because with the stick hard forward it was very near to the stall. Scheidhauer refused to do these tests. The spin was entered with full aileron and rudder, and recovery after two turns was by centralising aileron and rudder and pushing the stick forward. After one turn the aircraft slid sideways out of the spin with about 60° sideslip and went into a dive.

General flying characteristics were most unpleasant.

Note on the H III, the dimension "pfeilmass" is about 10% greater than the mean chord, so that static margins can be taken as % mean chord for rough comparison.

5.3 Tests on laminar flow

In the course of his work on laminar flow sections Horten carried out some observations on a 2 seater H III in which transition was detected by a creeping total head tube connected to a stethoscope, worn by the passenger. Transition from laminar to turbulent flow was accompanied by a roaring noise in the earpieces.

Results of the H III experiments were quoted as follows:

C_L	Transition point % C back from nose	
0.1 to 0.2	30% upper	60% lower surface
1.2 to 1.4	10% upper	80% lower surface

Chord at the test section was about 3 m and forward speeds about 10 m/sec at high C_L and 30 m/s at low C_L.

5.4 C_L max

None of the Horten designs claimed very high $C_L$max values. The following table summarises the maxima stated for various aircraft.

Type	C_L max.	Comments
H III	1.3 (no flap)	Measured
H IV	1.4	Measured
H VI	1.5	Estimated
H VIII	1.4 (no flap) 1.6 (flap)	Estimated
H IX	1.3 (flap)	Measured on V.1

C_L max. measurements were made with a swivelling pitot static held below the aircraft on a 4 metre pole which could be retracted for take-off and landing.

5.5 Waggle tip control

This device was first tested, unsuccessfully on the first H V (para. 3.7) and later more successfully, on a special H III (Fig. 27). The final objective was a "stockbrokers" aeroplane with a throttle and rudder bar as the only controls. Fig. 26 shows the principle of operation and Fig. 27 four shots of the damaged wing of the H III (found at Göttingen) with the waggle tip in its extreme and mean position. The wing tips were mounted on a skew hinge so that forward and backward sweep was accompanied respectively by increase and decrease of incidence.

In the form used on the H III the wing tip was geared to the stick, but finally it was proposed to have the tips freely floating but damped. The diagrams of Fig. 26 describe the automatic stabilisation as propounded by the Hortens. Control in the free floating case was to have been by spoilers on the wing tips, operated by the rudder bar. Opening of one spoiler would drag back the wing tip and apply bank and yaw in the correct sense for a truly banked turn.

Preliminary flights with the H III were apparently not very successful because of the large control inertia.

References:

No.	Author	Title etc.
1		Report of C.I.O.S. team visiting target No. 25/151 at Bonn near Cologne, March 1945.
2	Two articles by Horten	Flugzengkonstruktion. Bericht über die Sitzung Nurflugel flugzeng am 14 April in Berlin (Lilienthal Gesellschaft fur Luftfahurt-forschung)
3	Horten	Problem of the all-wing aircraft (Flugsport June 10th 1936)

References (contd.)

No.	Author	Title etc.
4	Horten	Nurflugelflugzeng "Horten IV" (Flugsport Feb. 18th, 1942)
5	Horten	"Horten IV" Konstruktionseinzelheiten (Flugsport March 31st, 1943.

Attached:

Drg. Nos. 17890S - 17903S inclusive
Neg. Nos. 64867 - 64878 65658 inclusive
Appendix I - II
Table 1 - 3

Circulation:

D.D.S.R.1	Action copy. 1+20
A.D./R.D.T.1	
R.T.P./T.I.B.	110+1
D.D./R.D.A.	
T.A.A.C.	20 per D.D.S.R.1
A.I.2g	
A.D.I.(K)	2
A.R.C. (S.C)	36
B.I.O.S. Secretariat	4
Director	
D.D.R.E.	
D.D.A.F.	
Library	
F.I.S.	
S.M.E.	
Aero (1)	
T/A	
P	
S	
F	
F/S	
E	
W.	

Appendix I

Centres of Horten activity

The following places were investigated during June 1945 in an attempt to locate and preserve the more interesting types of Horten aircraft.

1 Göttingen

This was the headquarters of Luftwaffe Kommando 9. The works were in a converted Autobahn workshop and comprised drawing office, machine shop, wood working shop, stores etc. Hangar accommodation was provided on the aerodrome about a mile away and test flying of a number of Horten aircraft including H III d, H III e, H IV and H XII had been carried on there.

Parts of the H VIII were found in the jigs with components such as fuel system and undercarriage parts in the stores; these were undamaged. All drawings had been taken and the drawing office reduced to a shambles.

The H IX, V1 and V2 were built at this centre.

2 Hersfeld

This centre was also located in an autobahn workshop with very similar equipment to the Gottingen works. All the buildings had been taken over by the U.S. Army as a transport depot and repair shop. The H X was under construction before the occupation, H XI and H XIV had been built there and H VI (second aircraft) finished after being started at Bonn.

No aerodrome was available near the works.

3 Kirtorf

The Kirtorf centre consisted of hangar space, limited workshop facilities adequate for glider construction, and a drawing office - all housed in aerodrome buildings on one side of the small grass airfield. Airfield and buildings had been heavily bombed before the occupation and had been abandoned by the Germans, who removed all drawings and the H I and H II which were stored there, and burned the H XII which must have been complete at the time.

4 Hornberg

The gliding school at Hornberg had workshops well equipped for glider construction and maintenance and was engaged in building wings for the Volksjäger. The Hortens had drawing office space over the main hangar and several of their gliders, including an H IV, H IIIb e H IIIg, had been housed in the school hangars. No construction was in progress, work seems to have been confined to assembling and flight testing gliders built at Dornsdorf and Tübingen

The main hangar complete with offices and aircraft was completely destroyed by a rocket bomb attack in April 1945, and the remainder of the gliders were broken up by the U.S. Army after the occupation.

5 Gut Tierstein

This was a small wood working shop housed in a farm near Rottweil am Neckar in the Black Forest area. Main wing panels for the H IVb were being made. Production rate was about 2 sets per month. Master drawings for the H IV b were on the farm and an H III f, H III g and H IV were hidden in barns nearby after evacuation from Hornberg.

The craftsmen working on the gliders lived on the farm and also did farm work.

6 Dornsdorf (near Goppingen)

A furniture maker (Schmidt) just outside the village was producing wings for the H III. The complete jigs were still in the workshop and two complete spars, a number of ribs and sufficient material for several sets of wings were lying about. 12 complete wing pairs had been burnt on April 15th on orders from the Hornberg.

7 Tubingen

A small engineering works was making the steel tube structures for the H III gliders and powered gliders. Production again about two per month. These centre sections were to fit the wings made at Dornsdorf and the aircraft were to be assembled and tested at the Hornberg.

8 Goppingen

The Hortens had hangar and maintenance facilities on the aerodrome where the H XIII was being tested. No constructional work was in progress.

9 Tamm

A large furniture works here (May g.m.b.h.) was engaged in building Klemm 35 wings in large numbers. Twenty pairs of H IX wings were ordered in the summer of 1944 and one pair was finished by Xmas.

10 Minden

The Peschke Fluzengbau were working under Horten direction and had completed one H VII and nearly finished a second. They also repaired Fiesler Storch aircraft and made ailerons for F.W. 190's. The first H VII was flown from the nearby airfield at Minderheide where it was found destroyed.

The firm itself was of the furniture building type and knew nothing about aircraft design. All work was from Horten drawings. Labour was almost entirely foreign, mostly Russian, Dutch, French and Polish; much of it was female.

11 Gotha Wagenfabrik - Friedrichsroda

Gotha were charged with the job of productionising the H IX. They were nearing completion of the V3 and were believed to be setting up for quantity production. Their initial work was on the centre-section of the aircraft.

12 Hedigienberg - Bonn

This works was not visited. It was responsible for the second

H VI and may have been building wing tips for the H IVb. The work was equipped by R.L.M. on the same basis as the Kirtorf, Göttingen and Hersfeld establishments.

13 Brandis bei Leipzig

Test flying of H IX V2 was going on on the airfield here. The Hortens had hangar and maintenance facilities.

14 Schwarz Propeller Werke - Eilenburg

An H 7 was taken to pieces and stored here, but the part of the town containing the target was in Russian hands in June and could not be investigated. No construction was thought to be in progress there. An H IVb and an H XIV were also reported hidden somewhere in the town or in Bernberg nearby.

15 Berlin - Oranienburg

H IX V1 and V2 were tested here in January 1945. An H VIII was also reported to have been tested. This centre was not visited and no Horten aircraft were supposed to be there in June 1945.

Appendix II

Flight Tests of the Horten II

The following is a translation of a German report on the flying characteristics of the Horten II and prepared by the well-known Hanna Reitsch.

Flight Tests of the Horten II, D-11-187 on the 17.11.38 at Rangsdorf

The Horten II was tested by Hanna Reitsch (D.F.S. Darmstadt) at the request of General Udet.

The type tested was built in 1934 and has since been followed and improved by the types H III, H IV and H V. (The Horten III was successfully flown in the 1938 Rhoen competitions and obtained a height of 8,000 metres (26, 000 ft.); it was destroyed in a hail storm but was flown again in 1939. The H IV and H V were completed in December 1938.) The following report on the flying characteristics must not therefore be regarded as representing the present stage of development of tailless aircraft by the Horten Brothers. The flying qualities do not correspond to present day demands. The following should however be noted: it possesses great static longitudinal stability and complete safety in relation to the spin.

Flying Characteristics

Since the builders of the Horten II did not have available sufficient raw materials for its manufacture, the resultant construction has made the testing very difficult. For lack of ball bearings the control surfaces are so heavy that measurements of stability cannot be carried out.

(A) Cockpit

(i) Comfort. Not exceptional.

(ii) View. View is bad since the edges of the cockpit hood cut off the view at eye level.

(iii) Entry and Exit. Only possible for athletes.

(iv) Parachute arrangements. Satisfactory.

(v) Arrangement of the Instruments. Not very satisfactory.

(vi) Arrangement and operation of the retractable undercarriage. Only possible for long armed pilots.

(vii) Friction of the control surfaces. Unsatisfactory.

(B) Take-off and Landing Characteristics

Take-off

The carrying out of the normal take-off technique is not recommended because of the long run that results. The take-off is best carried out with fully back control column until the aeroplane rises from the ground.

without change of incidence. When two or three metres height is reached the control column may be put so forward so that the aeroplane attains a normal flying attitude. It is thought that the long take-off which otherwise results is caused by the unsatisfactory arrangement of the undercarriage.

Landing

Landing, even on a small field, is easily made by means of the landing flaps and use of the drag rudders on both sides so that they act as dive brakes. Landing run is normal.

(C) Balance and Stability

Balance and stability could not be adequately tested because the control column would remain in any position in which it was put because of friction. Static longitudinal stability is good.

(D) Controlability and Control Forces

Longitudinal Control

The motion is strongly damped. Loads are normal.

Lateral Control

The response is inadequate and unpleasant due to a large negative yawing moment which appears when the controls are displaced. The control forces could not be accurately judged due to the friction and also buffeting of the control column caused by gusts. This fluttering of the ailerons is probably caused by the lack of static balance of the control surfaces. The over balance of the controls also gives a feeling of lateral instability which however does not appear in calm air.

Directional Control

There are upper and lower surface spoilers on the outboard wing. When they are operated a response occurs suddenly. Operation of the directional control suddenly slows down the inner wing and the aeroplane turns immediately about both the vertical and the longitudinal axes.

The relations between the forces on the three controls is not satisfactory.

(E) Turning Flight

Turns are only possible with difficulty. That is to say they are impossible with ailerons alone and can only be made using the drag rudder.

Manoeuvrability

If strong drag rudder movement is applied, manoeuvrability is good. The true bank can not be easily obtained (it must be noted that the test pilot could not retract the undercarriage and this would adversely influence the banking properties).

(F) Side Slip

Side slipping cannot be carried out on the Horten II.

(G) Characteristics in the Stalled Flying Condition

The aeroplane cannot by any sort of control movements be made to drop the wing or to spin. With the control column pulled right back the machine pitches slightly forward and sinks without reaching a speed of more than 90 kilometres/hr. (This is a great help in blind flying when the instruments are iced up.)

General

The above failings are to be taken up with the Horten Brothers with regard to further developments of the machine.

Darmstadt Airfield 12.11.38.

Table 1

Data sheet for Horten Aircraft

Type		I	II	III	IV	IVb	V	VI	VII	VIII	IX	XII	XIII	XIV	Parabola
Span	ft.	40.7	54.1	65.6	65.6	66.3	52.5	78.7	52.5	131	52.5	52.5	40(app)	49.2	39.4
Wing area	ft^2	226	344	403	203	205	451	191	473	1680	566	343		150	355
Aspect ratio		7.27	8.48	10.66	21.3	21.5	6.1	32.4	5.8	10.2	4.9	8	4	16.2	437
Taper ratio		5.7	8.7	7	5.5	5.5	4.6	6	6.6	4.1					
$\frac{1}{4}$ chord sweepback	deg.	9.5	26	23	17	18	32	15	34	27	28	30(L.E.)	60(L.E.)	20(L.E)	
Total washout	deg.	7	8		7.1	5.6	5	6.2	5	7	1.8	3½		8.6	
Dihedral	deg.	3	3	3	5	5	3	5	2½	3	1.5				
Thickness ratio at centre section	(%)	20	20	20	27	27			17	18	16				
Wing root thickness		20	20	20	16	15.5	17	16	15	16	13			17	
Wing tip thickness		10	10	10	8	10	8	8	8	8	8			10	
Weight empty	lb.	264	606	550	440		2310	550						265	198
loaded		440	827	770	660		2760	770	7050	33000	18700	1550 (Glider)		485	375
Wing loading	lb/ft^2	1.9	2.4	1.9	3.3		6.1	4.0	15	19.5	33	4.5		3.24	1.01
Performance															
Best gliding ratio		1/21	1/24	1/28	1/37		-	1/43	-	-	-	-		1/30	1/19
Minimum sinking speed	ft/sec	2.8	2.6	2.13	1.77		-	1.58	-	-	-	-		2.03	2.13
Power units		-	-	-	-		2xHM60R	-	2xAS10c	6xAS10c	2xJumo 004	-	-	-	-
B.H.P.							2x80	-	2x240	6x240		-	-	-	-
Maximum speed	m.p.h.	-	-	-	-		134	-	212		590	-	-	-	-
Cruising speed	"	-	-	-	-			-	190			-	-	-	-
Landing speed	"	-	-	-	-		47	-	62			-	-	-	-

Table 2

Wing Sections from H IV (see Fig.9)

Section F.S. Chord ins. Dist. from C.L.	Wing root		Inner end of inboard elevon		Inner end of outboard elevon		Wing tip	
Ordinate % ch. Station % chord	Upper surface	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2½	4.01	2.44	3.88	2.83	3.27	2.57	2.76	
5	5.81	3.37	5.32	3.64	4.62	3.50	3.67	
10	8.28	4.30	7.24	4.36	6.26	4.44	4.56	
15	9.89	4.65	8.54	4.80	7.19	4.90	5.08	
20	10.91	4.82	9.40	5.04	8.08	5.14	5.37	
30	11.43	4.91	10.26	5.28	8.64	5.42	5.21	
40	10.69	4.91	9.40	5.08	7.89	5.37	5.14	
50	9.27	4.65	8.01	4.84	6.72	4.72	4.61	
60	7.09	4.04	6.23	4.22	5.37	3.92	4.12	
70	4.97	3.15	4.32	3.55	4.16	3.13	3.29	
80	2.92	2.25	2.64	2.64	2.80	2.33	2.18	
90	1.35	1.28	1.15	1.63	1.35	1.21	1.29	
44.25							0.49	
45			8.78	5.04			0.22	1.11
47.5							2.23	3.70
49.25					-2.57			
50			8.01	4.84	1.17	3.50	2.94	4.05
52.5					0.75	3.92	3.61	4.14
55			7.19	4.60	2.33	3.83	3.96	4.10
57.5					3.32	3.78	4.19	4.01
60			6.23	4.22	4.30	3.69	4.10	3.92
62.5					4.72	3.64	4.05	3.70
65			5.23	3.93	4.67	3.50		

Table 3

Wing sections used on the H IV b (see also Fig.10)

Section F.S. chord ins. Dist. from C.L.	Centre 72.8		Wing root 53.2	
Ordinate % ch. / Station % chord	Upper surface	Lower surface	Upper	Lower
Nose rad.	2.1		1.85	
2½	3.43	2.23	2.64	2.23
5	5.15	3.26	4.08	3.26
10	7.07	4.26	5.49	4.26
15	8.48	4.94	6.59	4.94
20	9.47	5.49	7.34	5.49
30	10.81	6.21	8.44	6.21
40	14.55	6.45	8.72	6.45
50	13.90	6.01	8.17	6.01
60	12.22	4.98	6.97	4.98
70	6.69	3.36	5.32	3.36
80	4.19	1.85	3.40	1.85
90	1.68	0.07	1.44	0.07
100	0	0	0	0

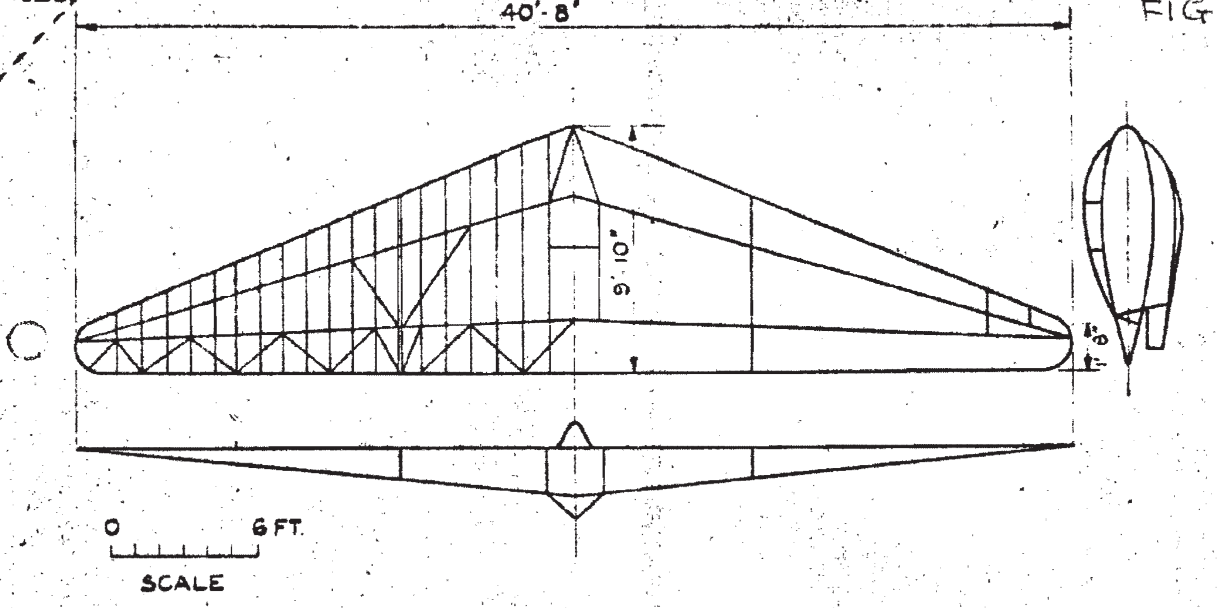
Table 3 contd.

Section F.S. chord ins. Dist. from C.L.	Wing tip 20.76	
Station % chord	Upper	Lower
Nose rad.	0.8	
2½	2.02	1.78
5	2.84	2.50
10	4.14	3.23
15	5.01	3.81
20	5.68	4.29
30	6.65	4.82
40	7.18	5.01
42.5	7.23	5.01
43.5	7.23	5.01
43.9	7.23 1.69	1.11 8.14
50	7.18	4.67
55	6.89	5.68
60	6.41	6.21
62	6.21	6.02
45	4.00	4.00
47.5	0.48	5.06
50	2.65	4.96
55	4.14	4.62
60	5.54	4.24
70	4.82	2.89
80	2.60	1.40
90	0.96	0.48
100	0	0

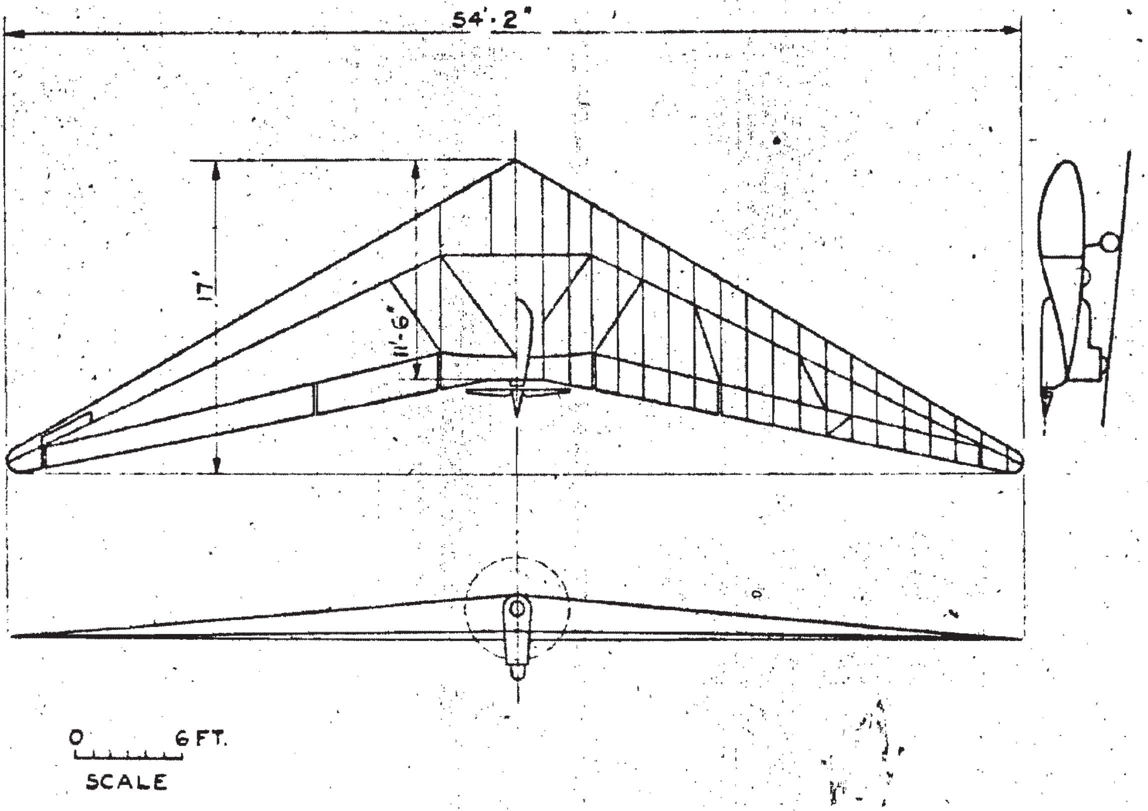
Nº 17890.S
DR. CBT
TR. 30-8-45
CH. [illegible]
APP.

FIG. 1

FIG 1.



HORTEN I



HORTEN II (POWERED VERSION)

HIRTH H.M. 60 R. ENGINE

17891S

DF [illegible]

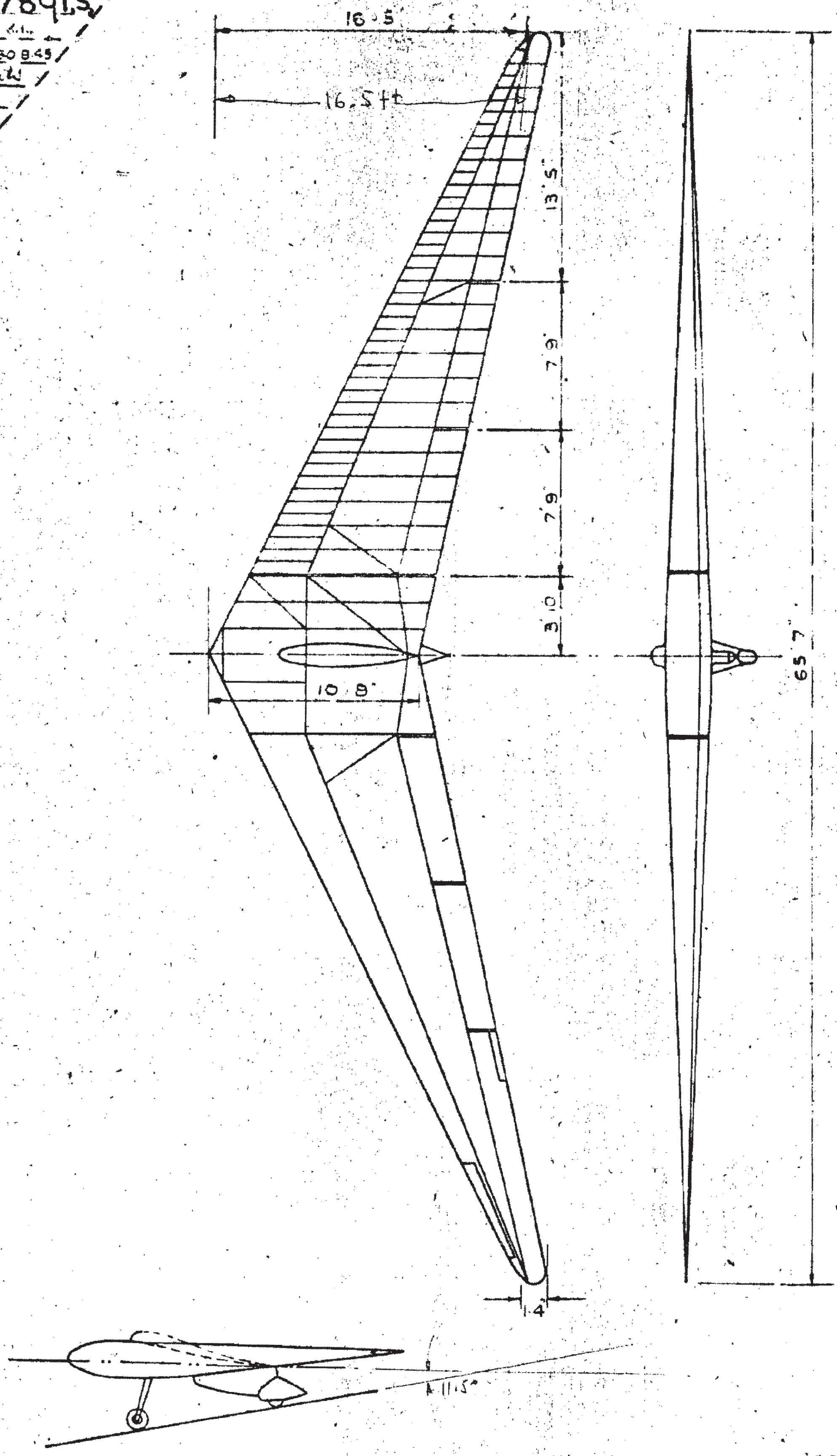
TR RL 30.8.45

CH [illegible]

APP

FIG.2

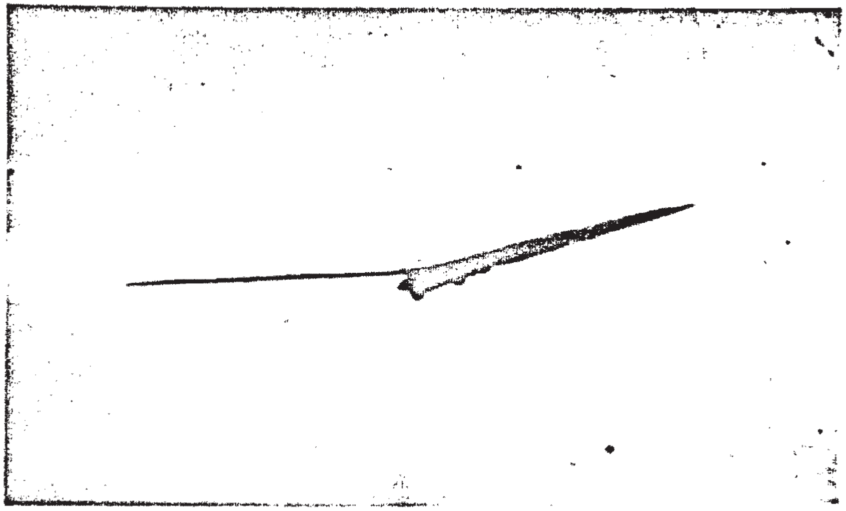
FIG-2



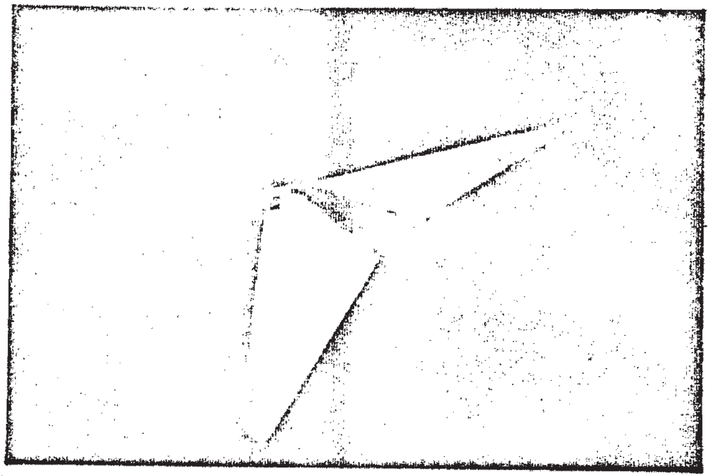
SCALE 0 6FT

HORTEN III

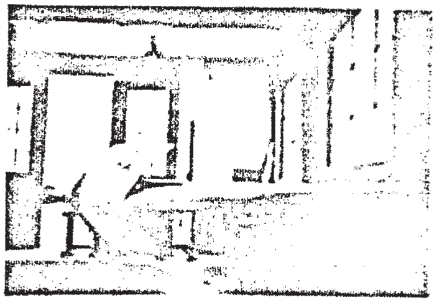
FIG. 3.



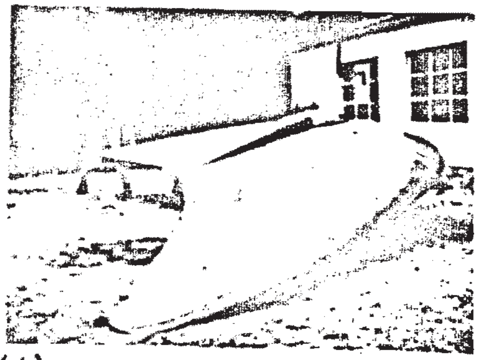
(a) HORTEN III b (GLIDER VERSION) IN FLIGHT.



(b) HORTEN III d. (POWER VERSION)



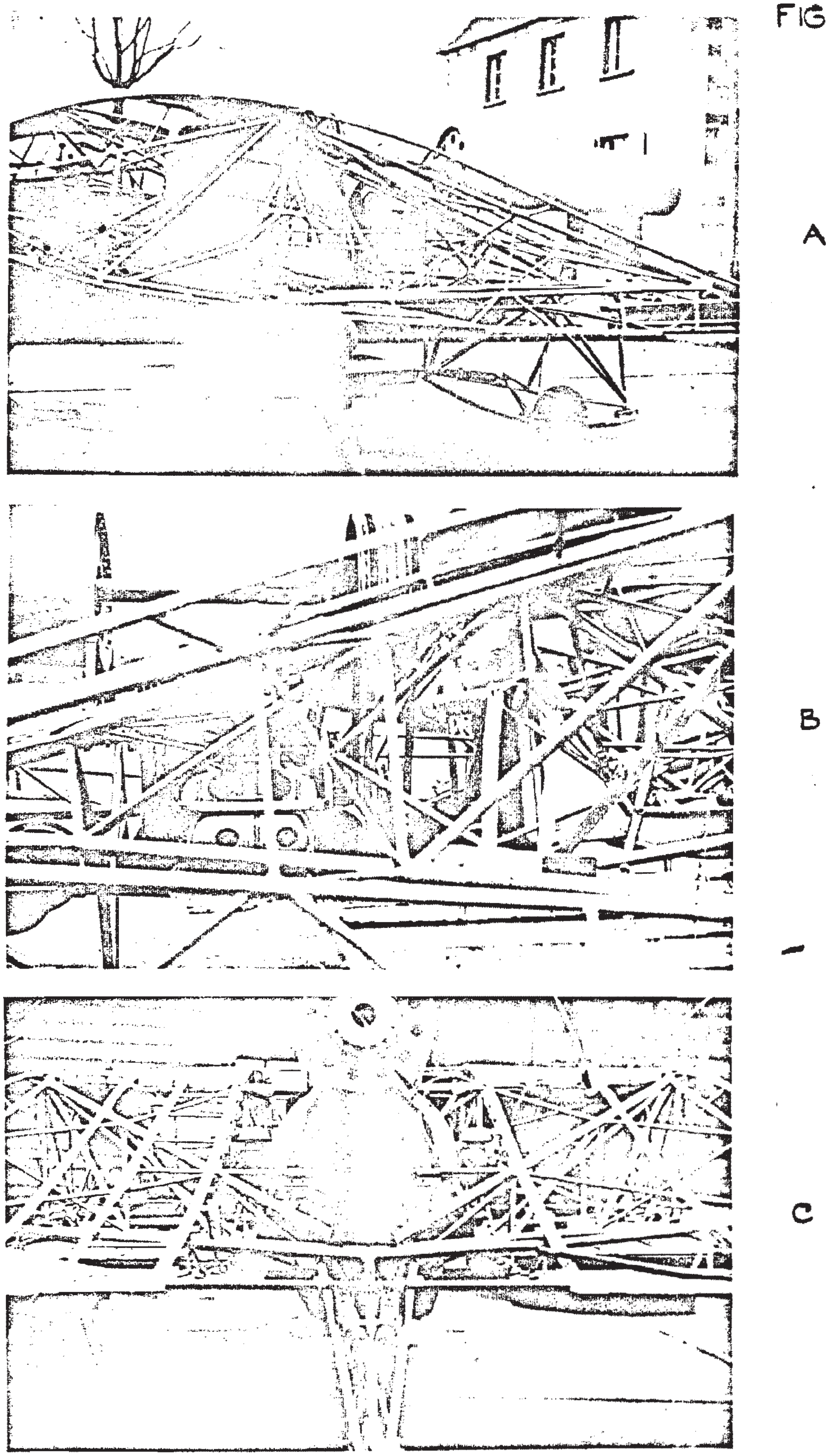
(c) HORTEN II & III TYPE DRAG RUDDER.



(d) HORTEN PARABOLA

ROYAL AIRCRAFT ESTABLISHMENT
COPY NEG. No 64867
DATE 5·9·45

FIG 4.



VIEWS OF 32 H.P. ENGINE INSTALLATION

HORTEN III d.

64868
5 9 45

11042.5.

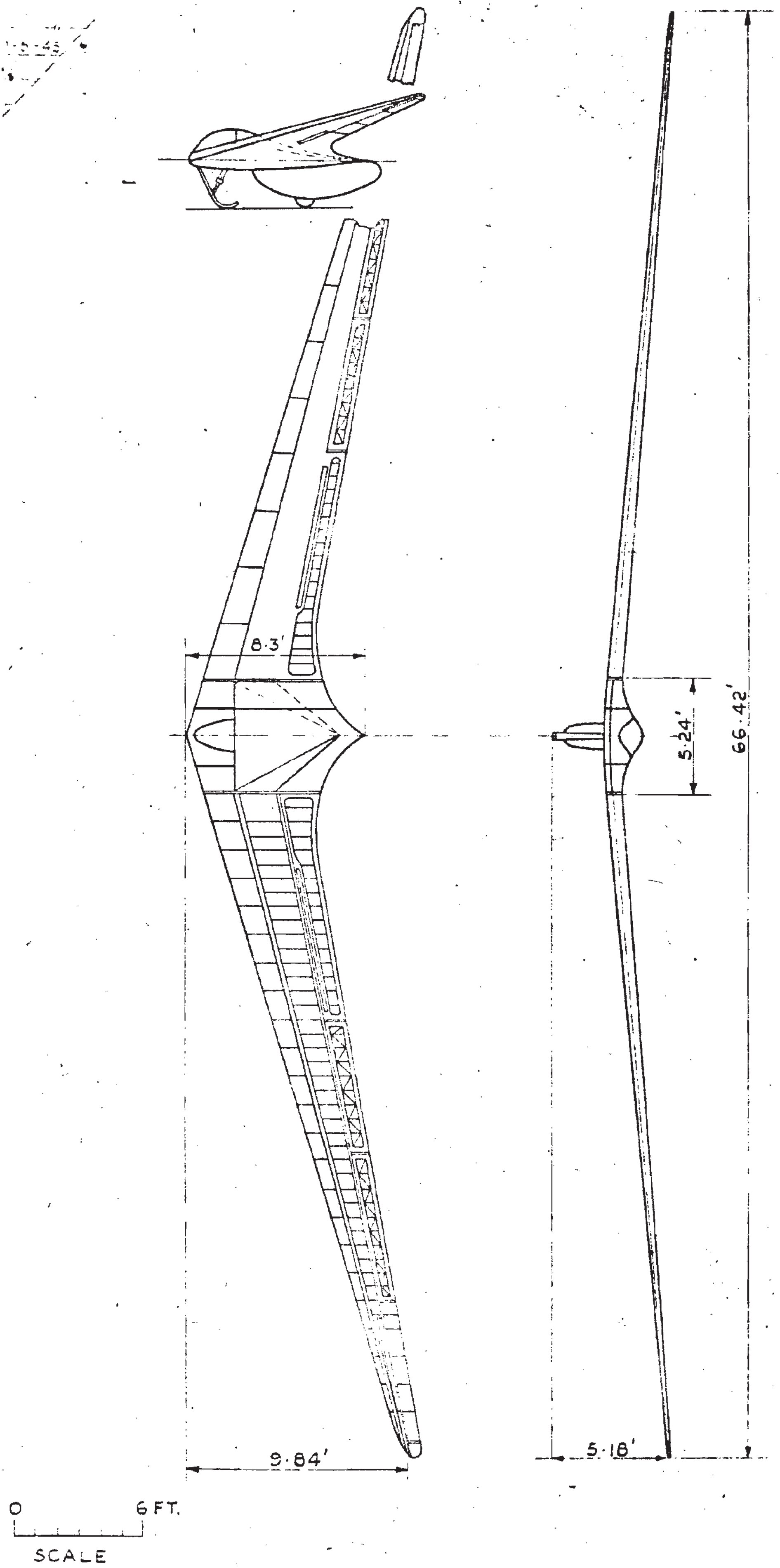
TR'N 15-3-45

CH'D

APP

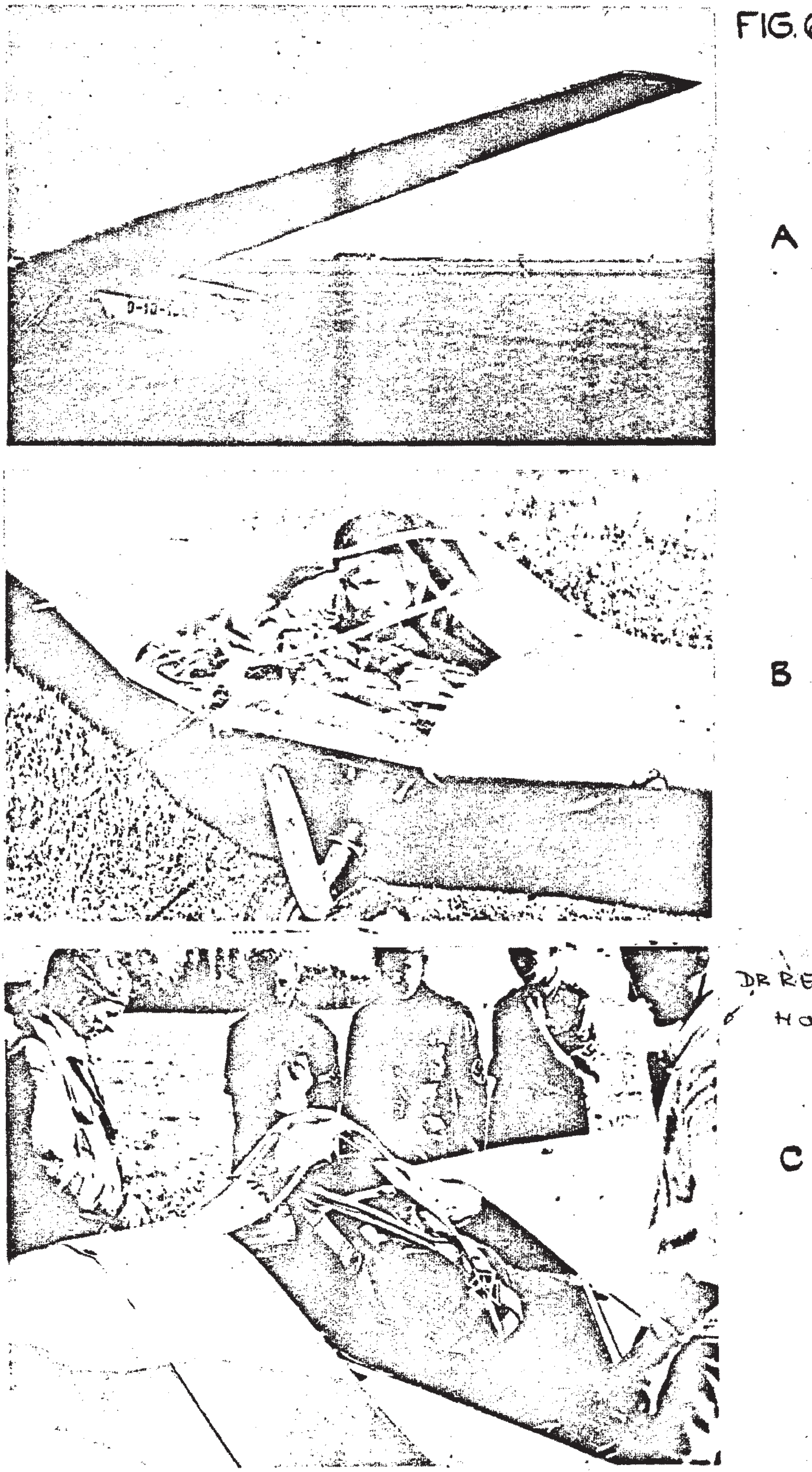
FIG. 5

FIG. 5



HORTEN IV b

FIG. 6.



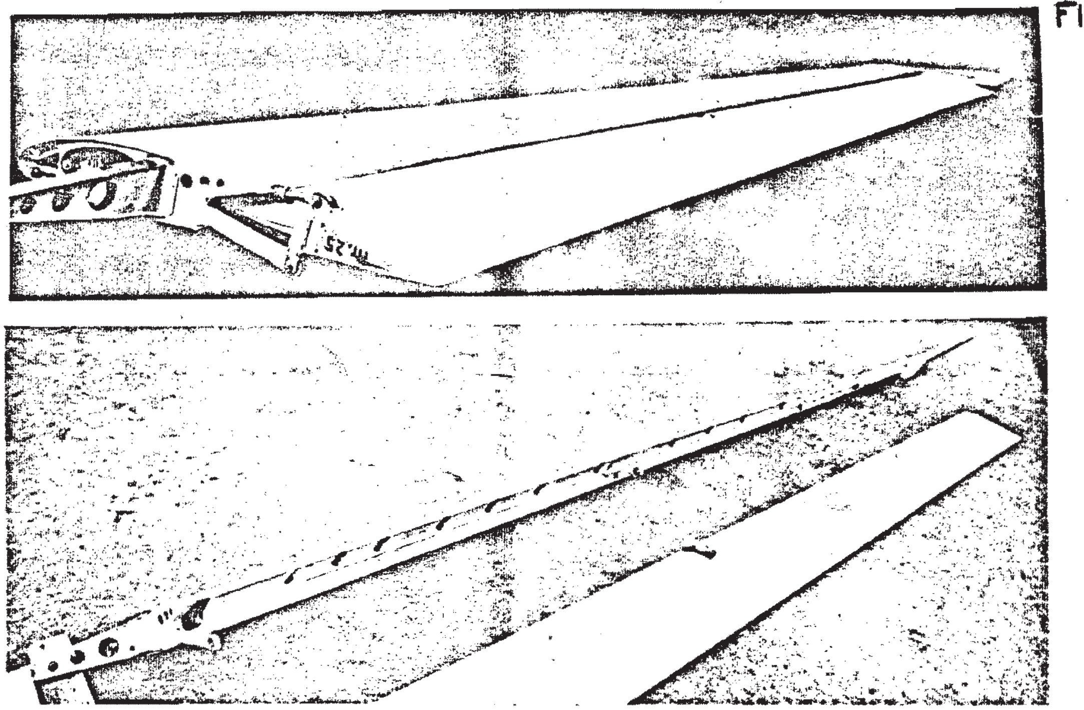
SCHEIDHAUER
(WO1. TEST PILOT)

DR REIMAR HORTEN

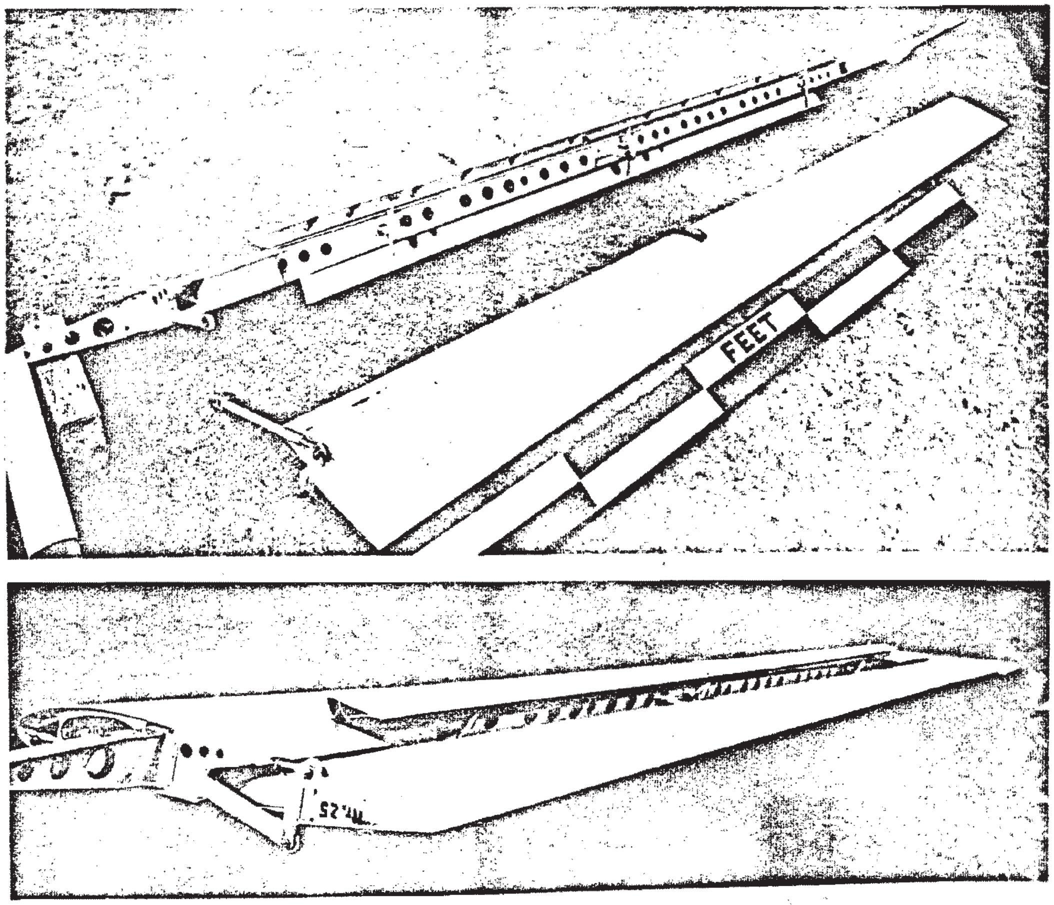
VIEWS OF HORTEN IV SHOWING PILOT'S POSITION

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC
COPY NEG No. 64869
DATE 5·9·45

FIG.7



(a) DRAG RUDDERS CLOSED.

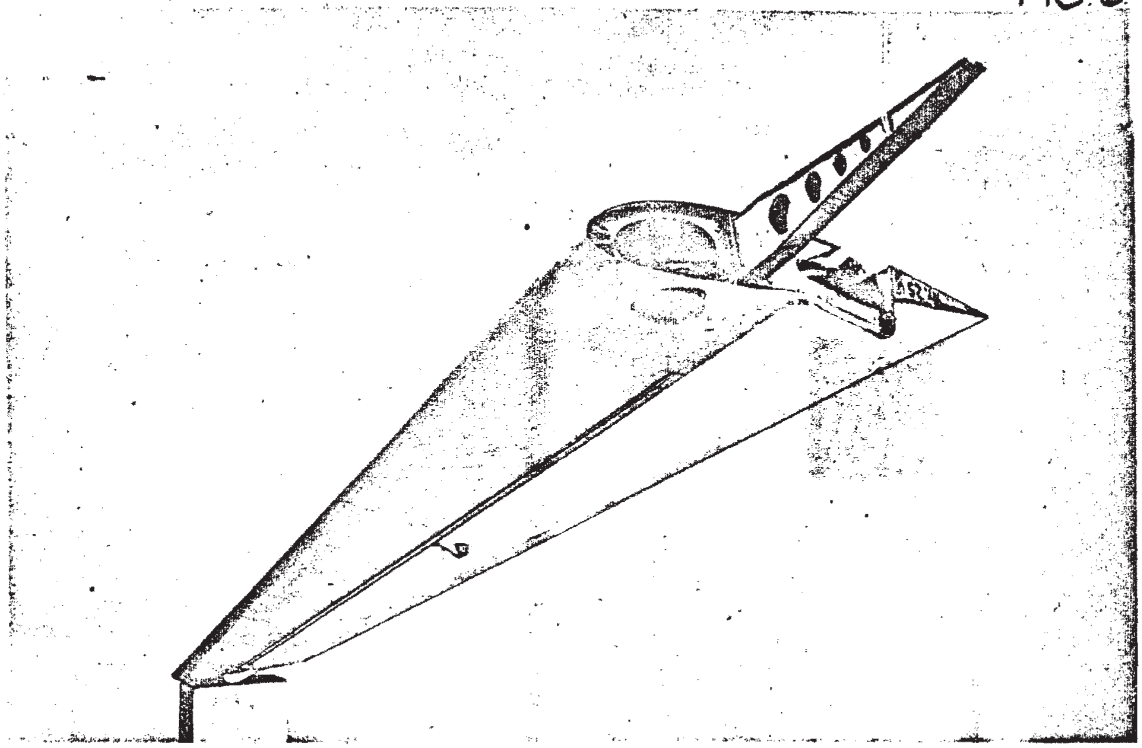


(b) DRAG RUDDERS OPEN - NOTE VENT HOLES.

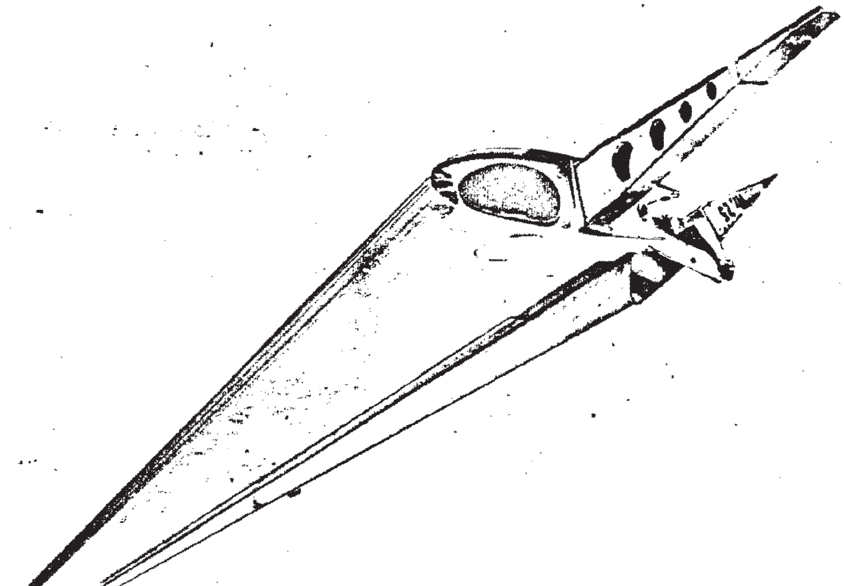
VIEWS OF HORTEN IV WING TIPS.

ROYAL AIRCRAFT ESTABLISHMENT
[illegible] 64870
[illegible] 5·9·45.

FIG. 8.



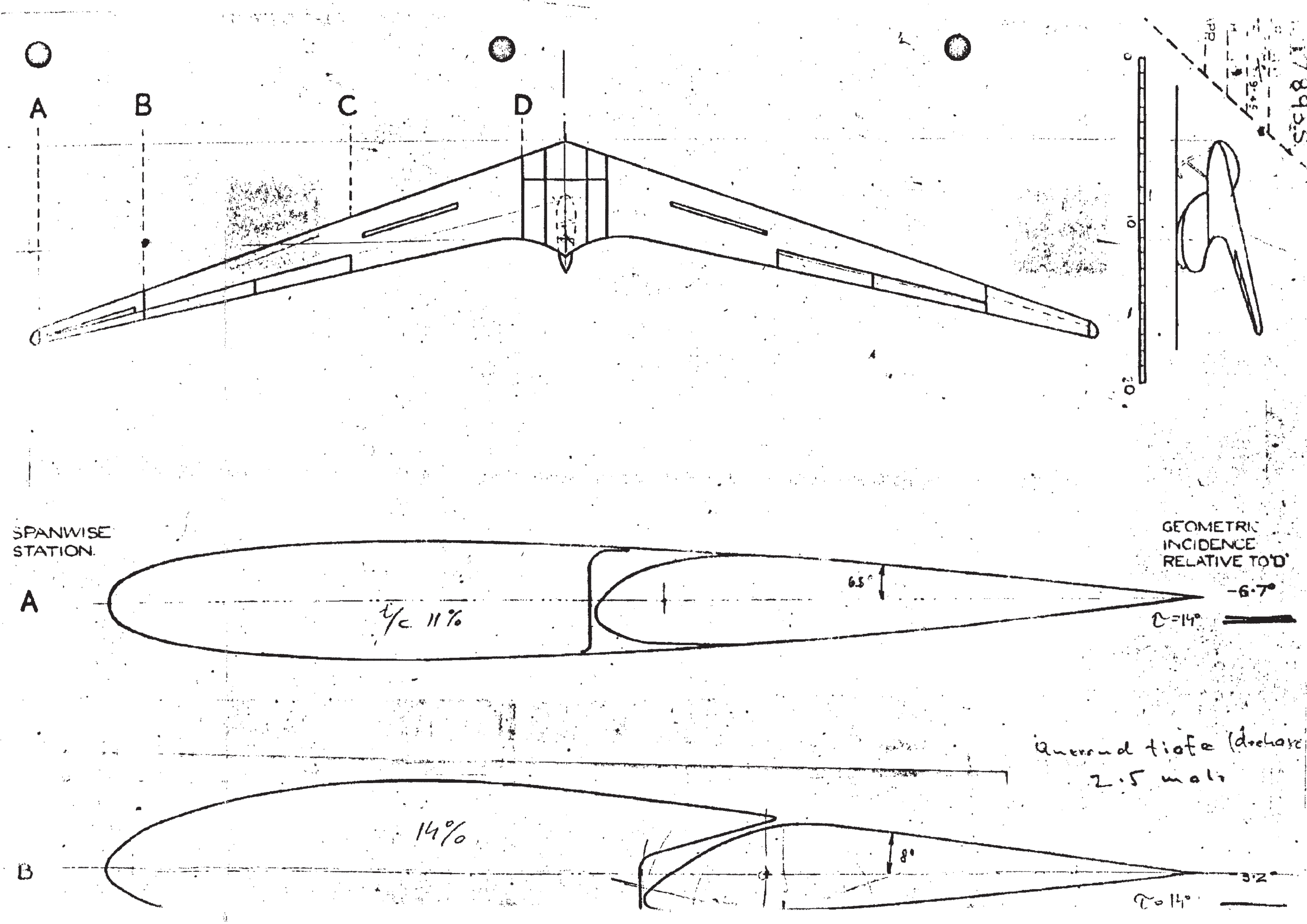
(a) ELEVON AT MAXIMUM DOWNWARD DEFLECTION.



(b) ELEVON AT MAXIMUM UPWARD DEFLECTION.

VIEWS OF HORTEN IV WING TIPS SHOWING SKEW HINGE FRISE BALANCE.

ROYAL AIRCRAFT ESTABLISHMENT
[illegible]
COPY NEG No – 64871
DATE 5·9·45

A
B
C
D
0
10
20
SPANWISE STATION.
A
t/c 11%
6.5°
GEOMETRIC INCIDENCE RELATIVE TO 'D'
-6.7°
τ=14°
Querrud tiefe (drehachse)
2.5 mal
B
14%
8°
3.2°
τ=14°

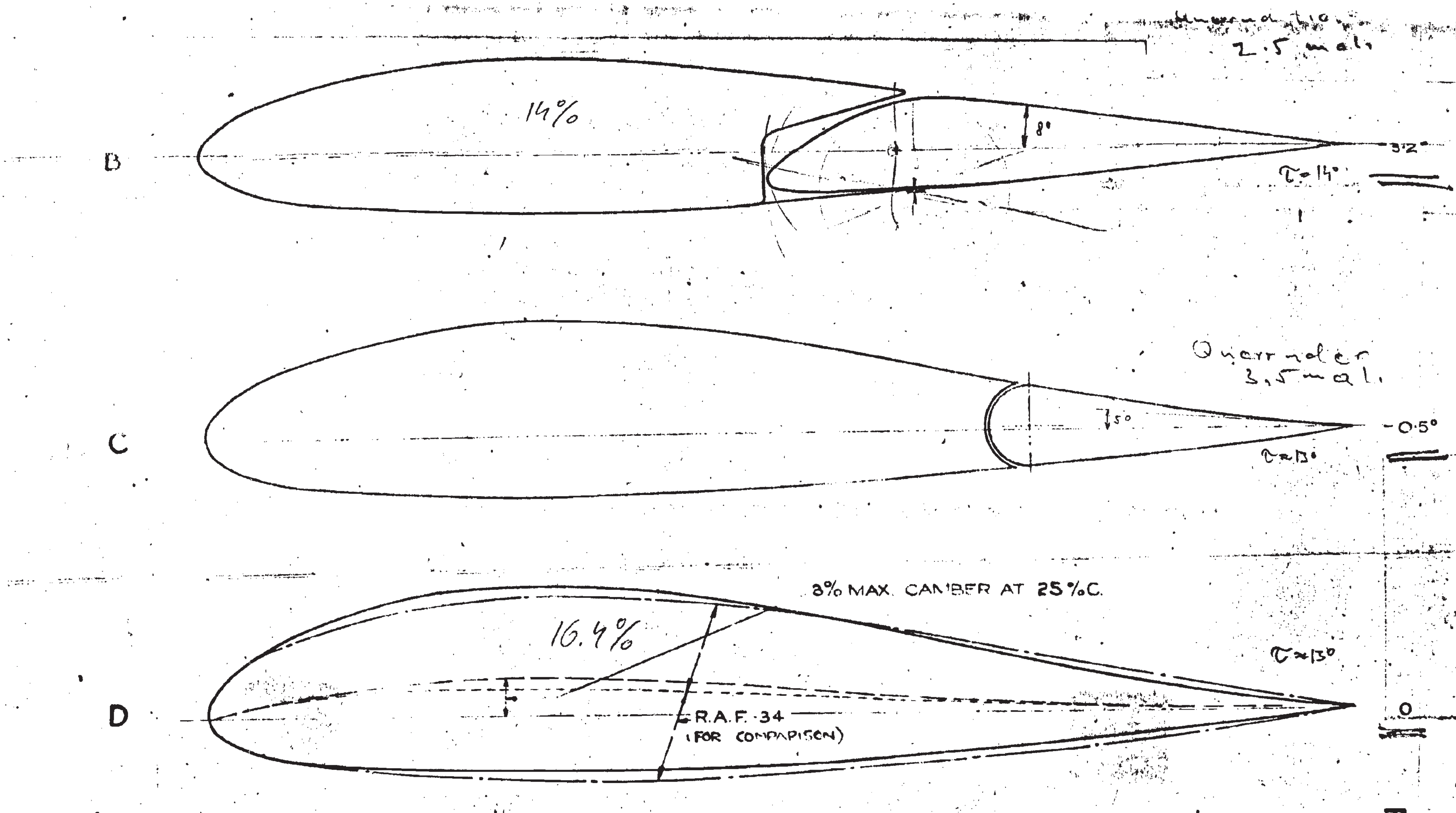
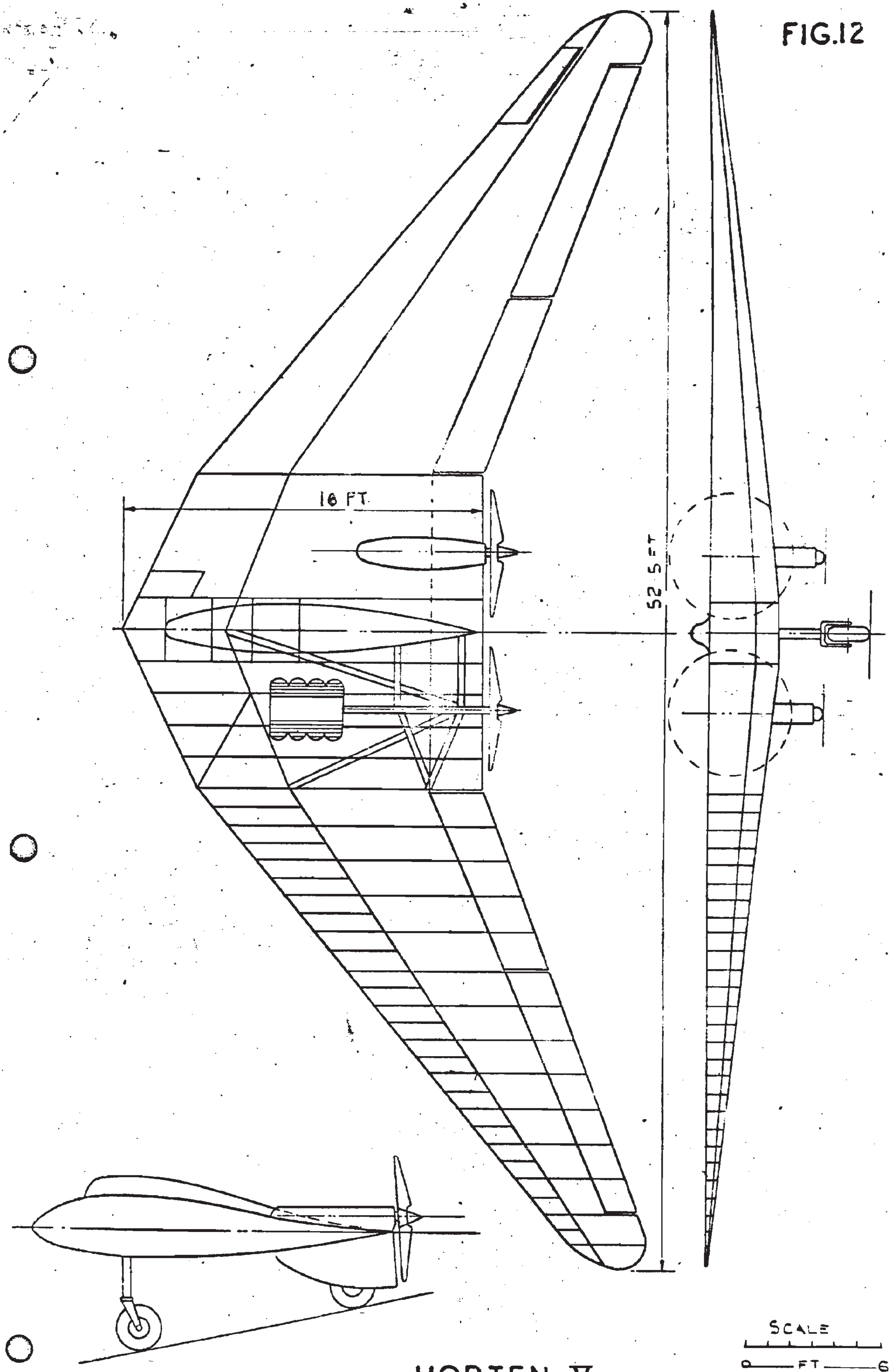


FIG. 9

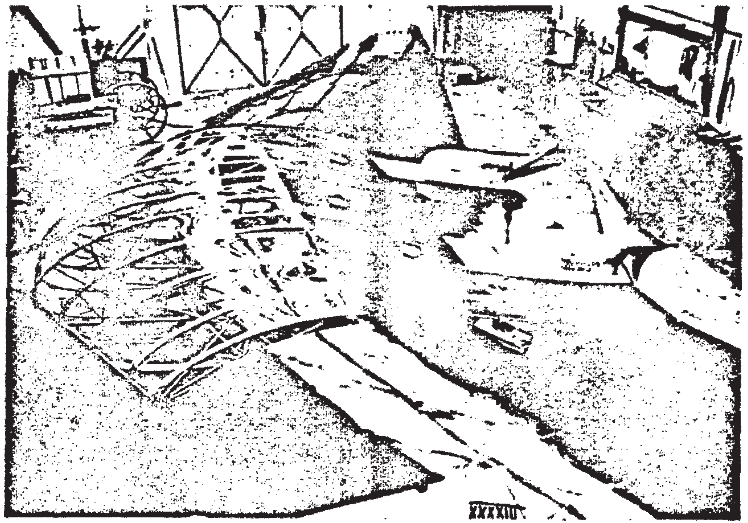
WING SECTIONS - HORTEN IV

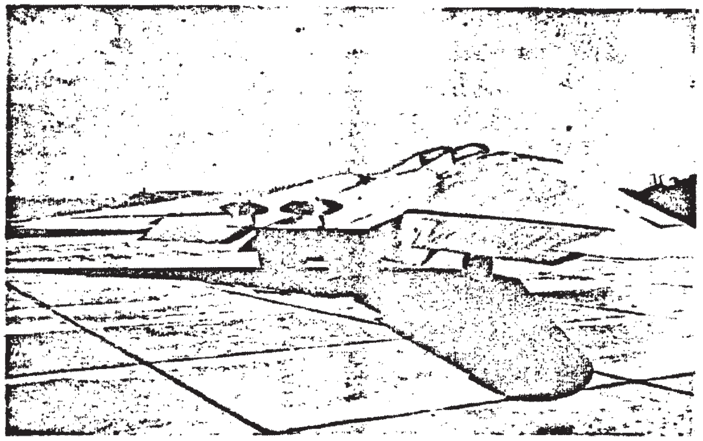
FIG.12

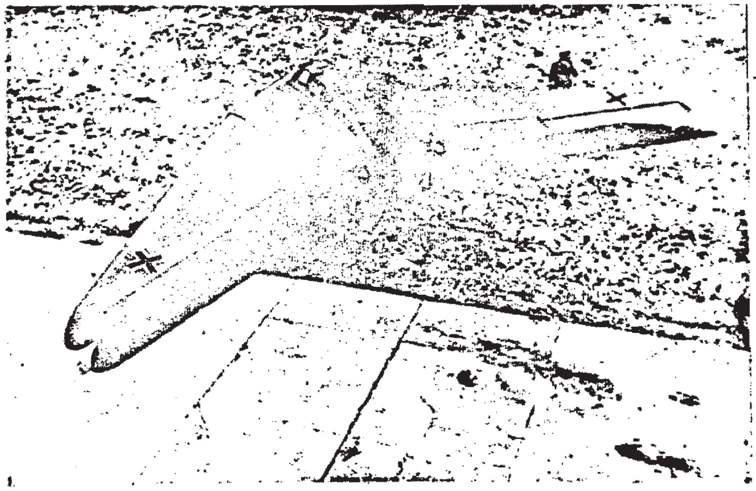


HORTEN V

FIG. 13.


(a) PLASTIC VERSION WITH WAGGLE TIPS. (1936)


(b) SECOND AIRCRAFT (WITH ELEVON-CONTROL) 1937

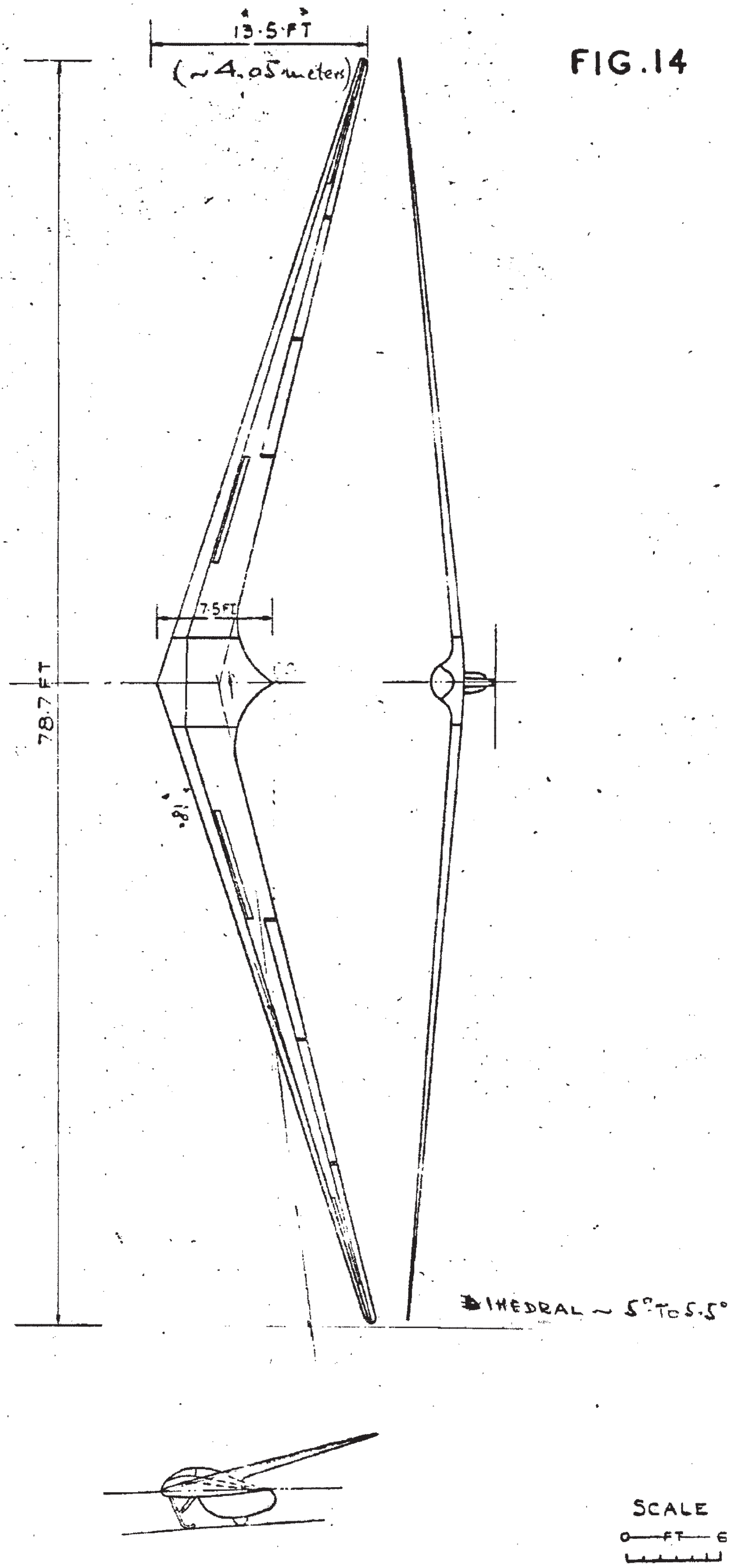

(c) IMPROVED SINGLE SEATER VERSION (1941)

HORTEN V DEVELOPMENT.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG No. 64872
DATE 5·9·45.

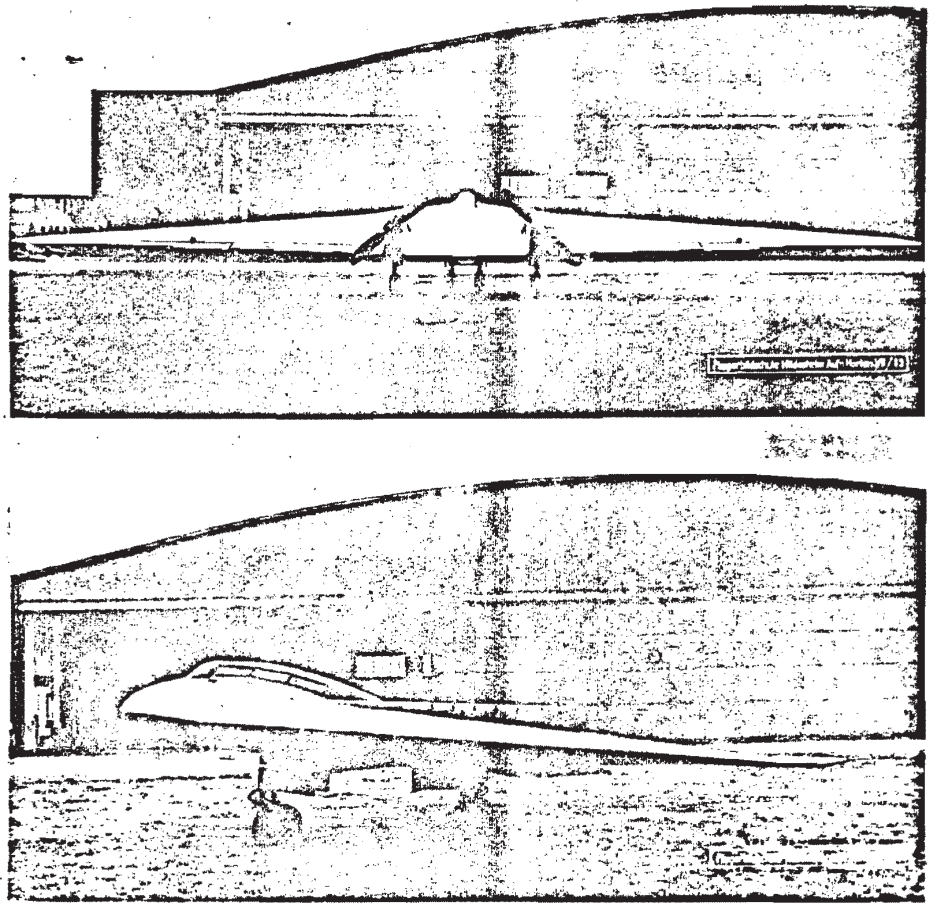
17897-S.
DR C.B.T.
TR 8-45
CH
APP

FIG.14

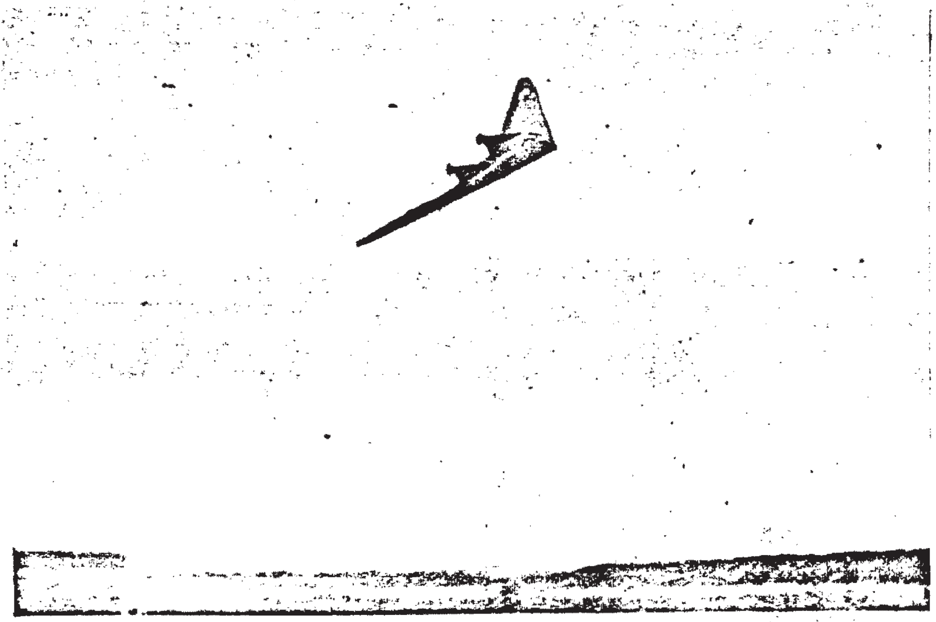


HORTEN VI

FIG. 18



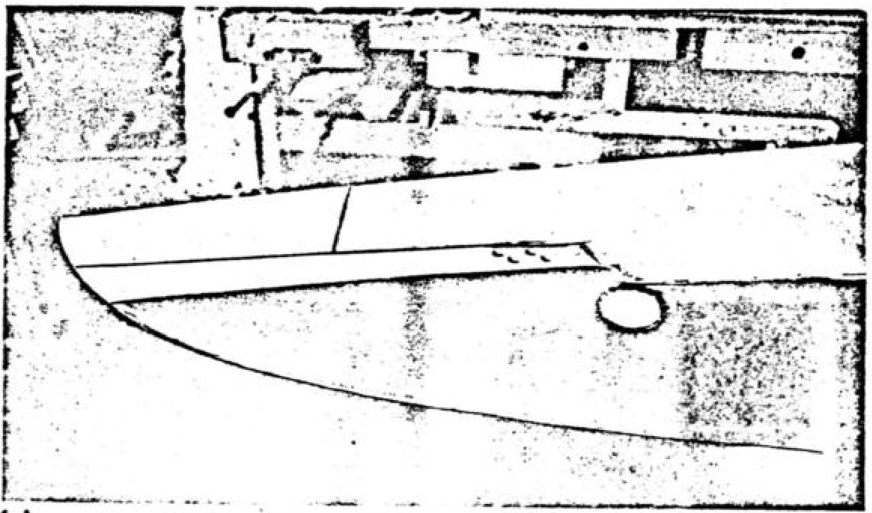
(a) HORTEN VII TWIN MOTOR COMMUNICATIONS AIRCRAFT.
(PROJECTED IN 1938, BUILT 1943)



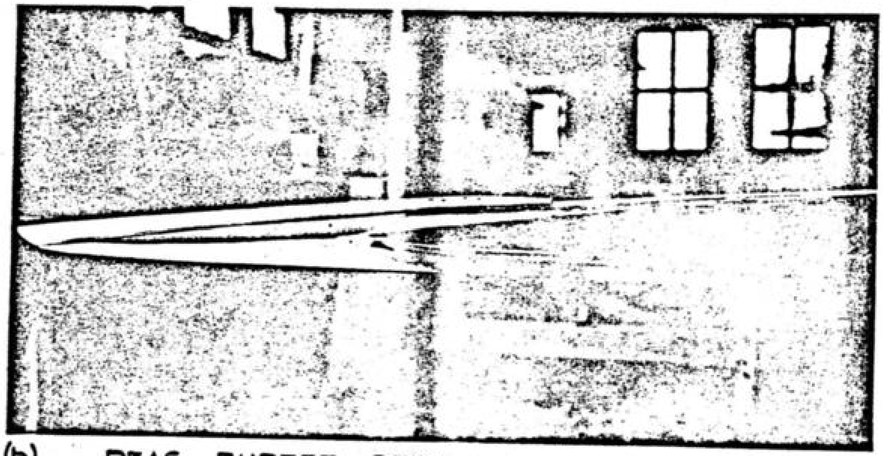
(b) HORTEN VII IN FLIGHT.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG No. 64873
DATE 5·9·45

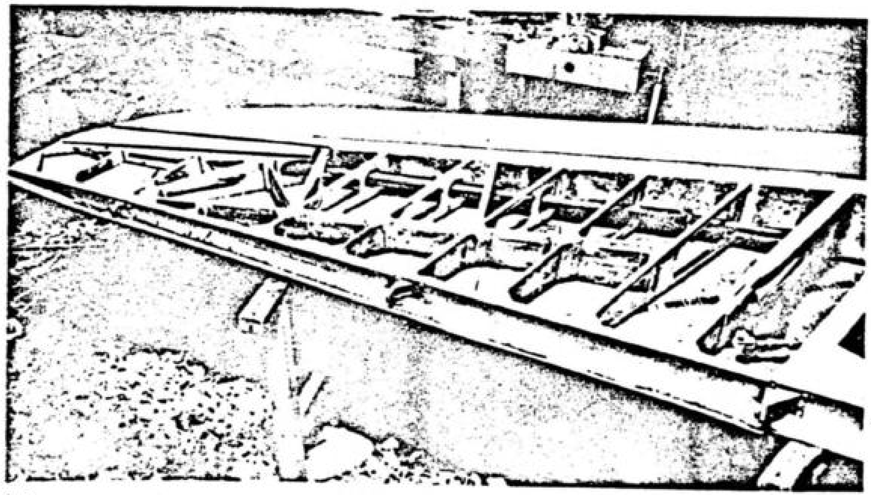
FIG. 17.



(a) DRAG RUDDER CLOSED.



(b). DRAG RUDDER OPEN.

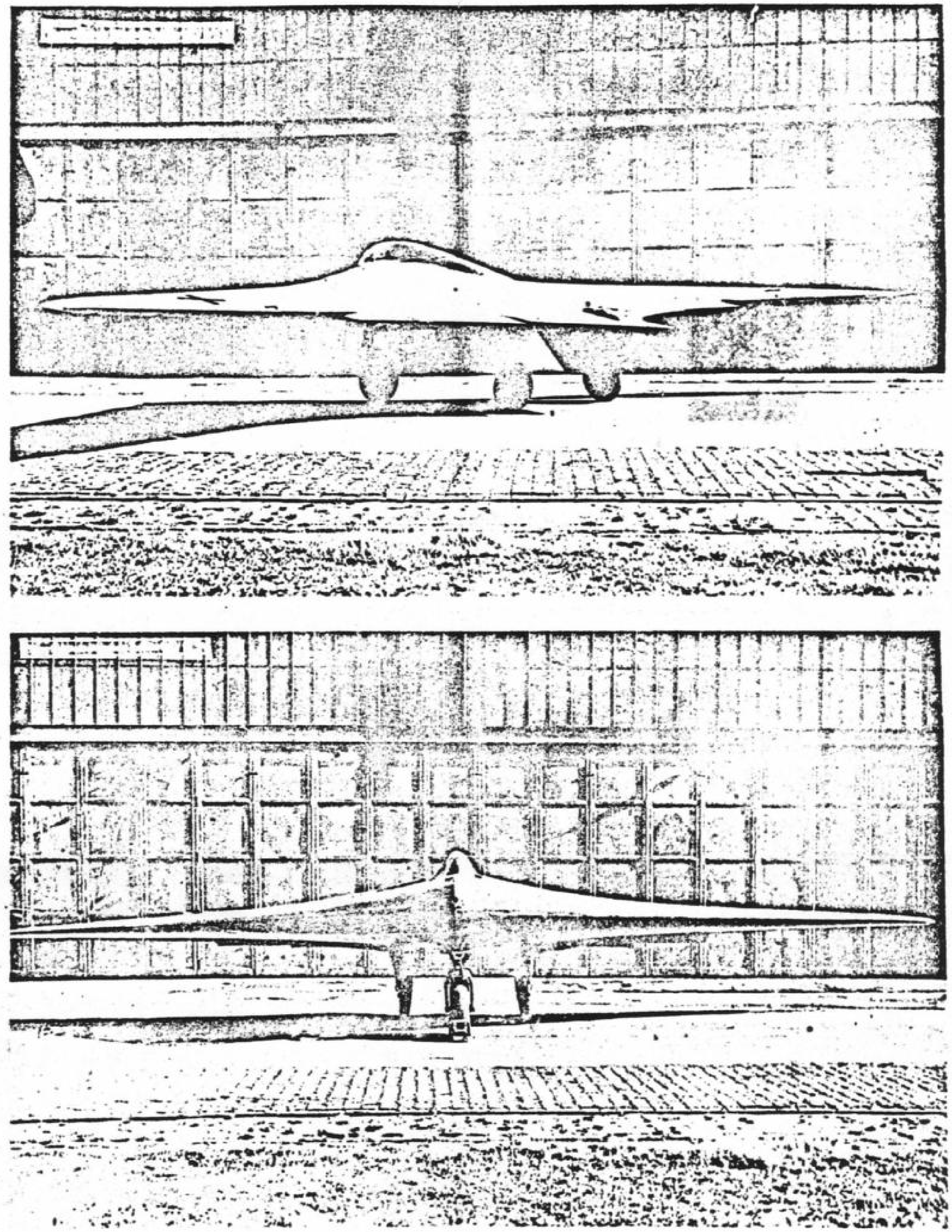


(c) VIEW FROM REAR SHOWING CONTROL ROD.

HORTEN VII WING TIP SHOWING
EXPERIMENTAL DRAG RUDDER.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG No 64874
DATE 5-9-45.

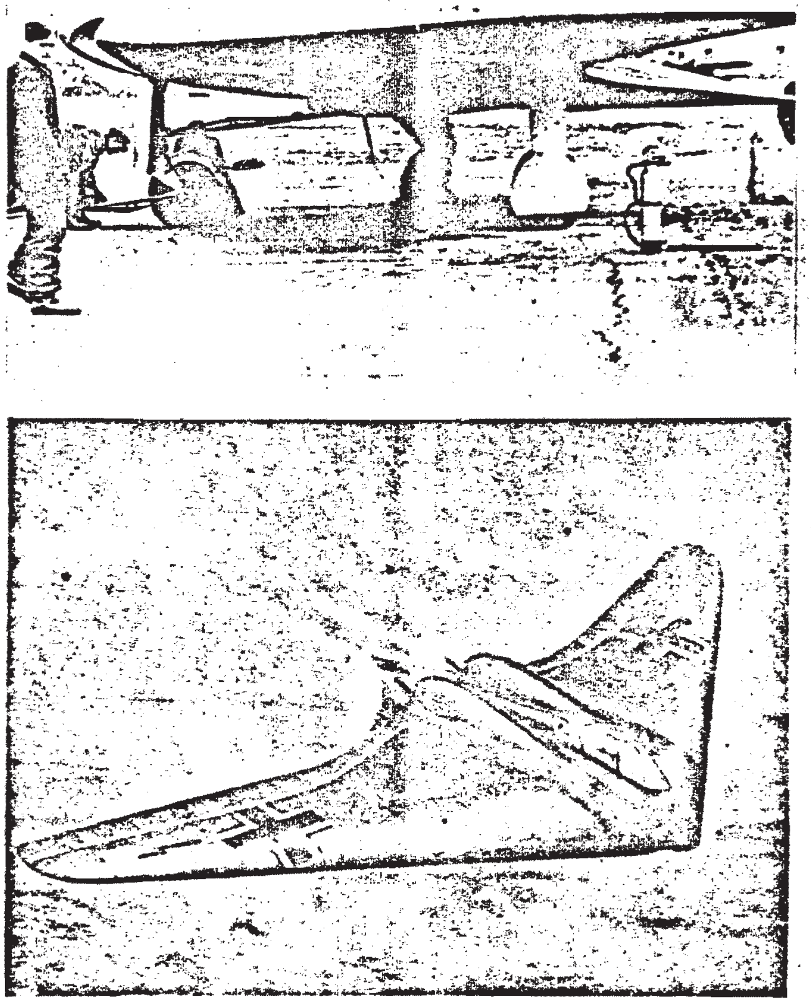
FIG. 20



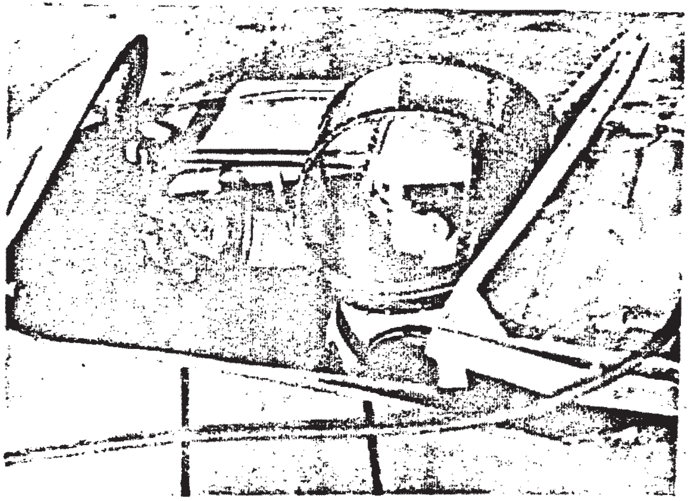
HORTEN IX MODEL V-1 (EXPERIMENTAL GLIDER)

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG No. 64875.
DATE 5·9·45.

FIG. 21.



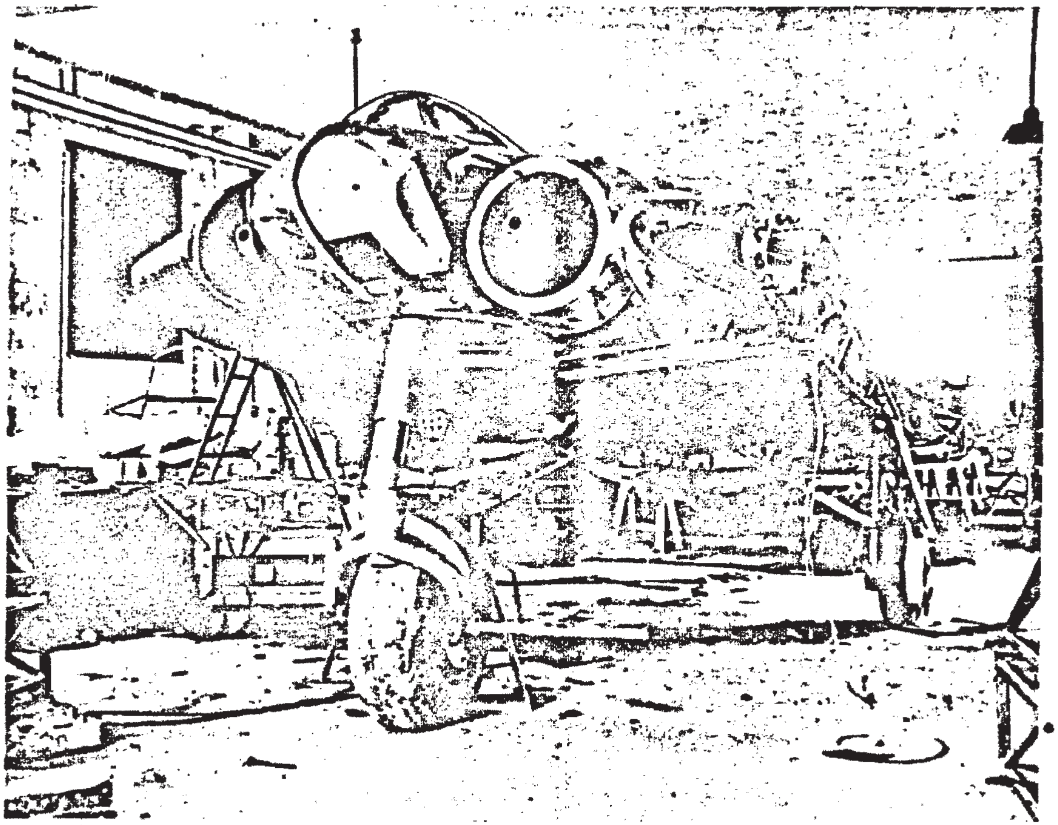
(a) VIEWS OF HORTEN IX



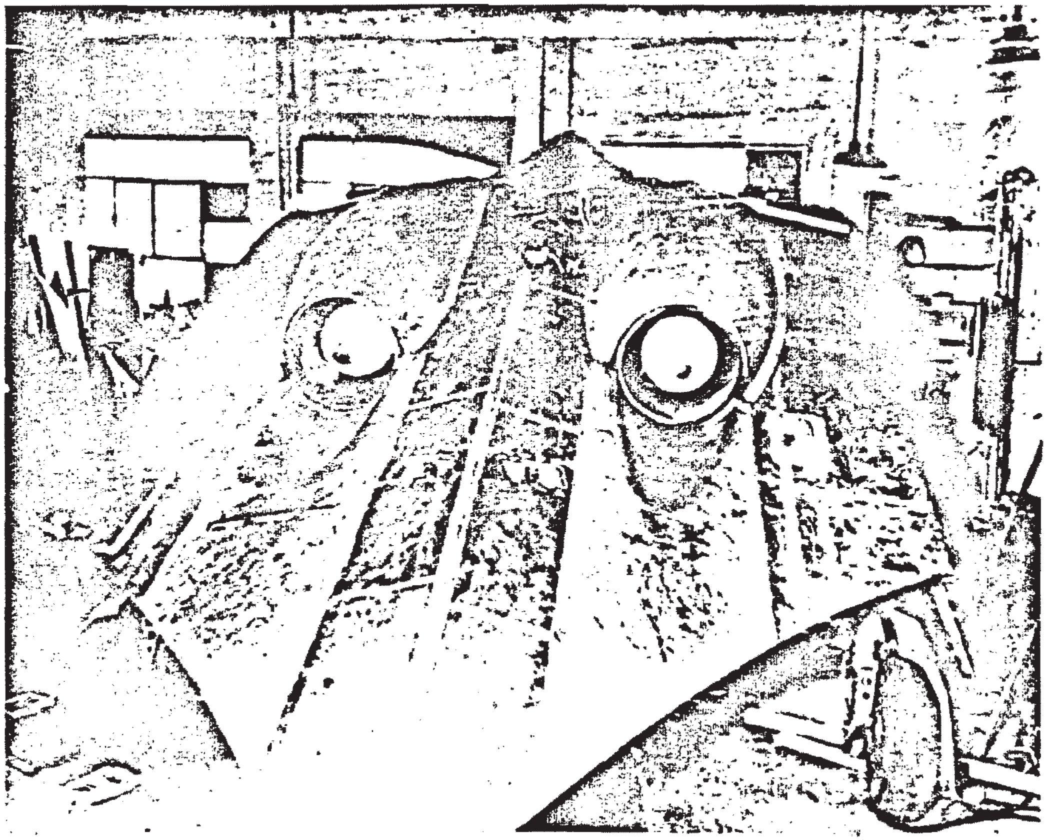
(b) PILOTS PRESSURE SUIT - HORTEN IX.

ROYAL AIRCRAFT ESTABLISHMENT
[illegible]
DATE 5·9·45.

FIG. 22.



(a) FRONT VIEW.



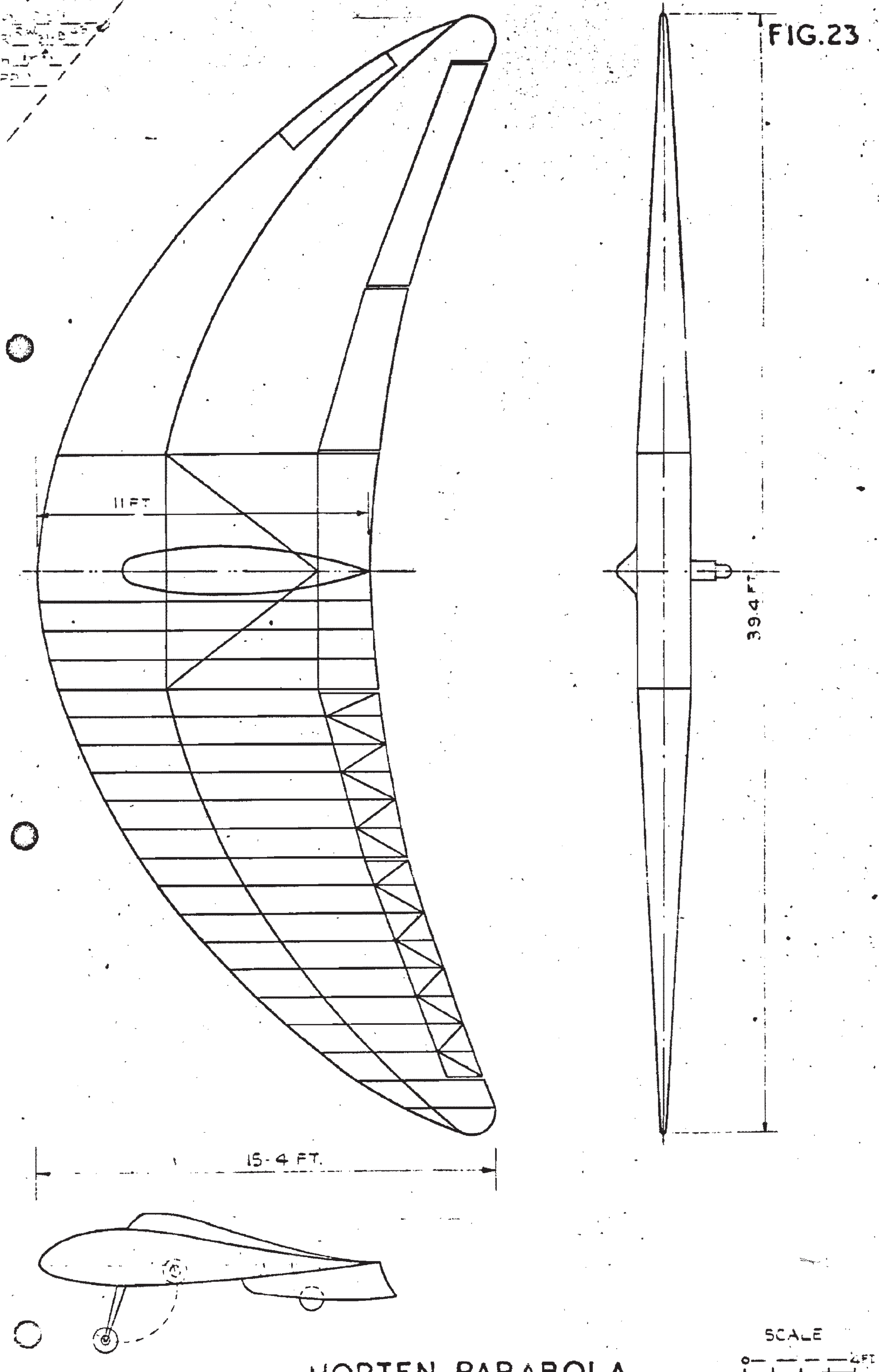
(b) REAR. VIEW.

HORTEN IX - CENTRE SECTION
SHOWING JET INSTALLATION.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG. No. 64877
DATE 5-9-45.

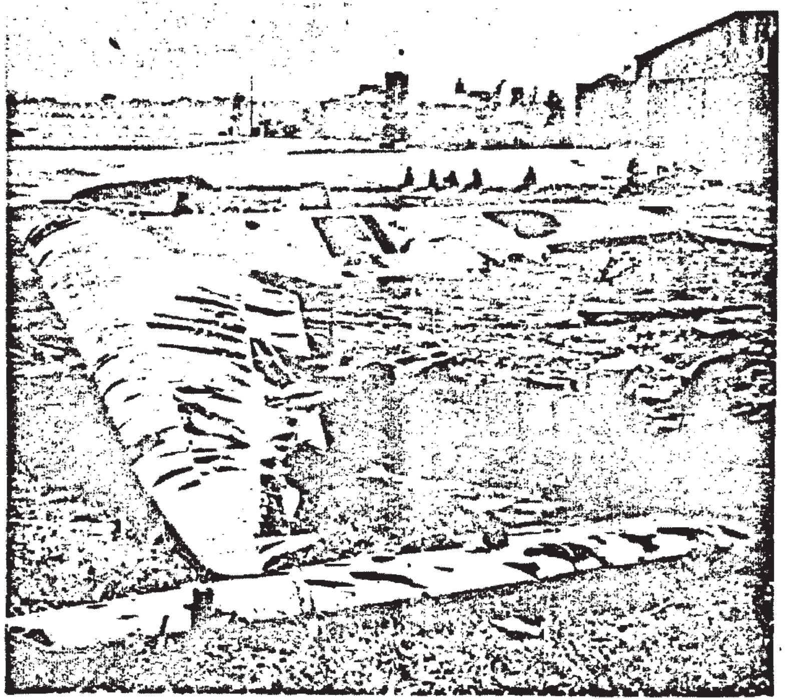
17901.S

FIG.23

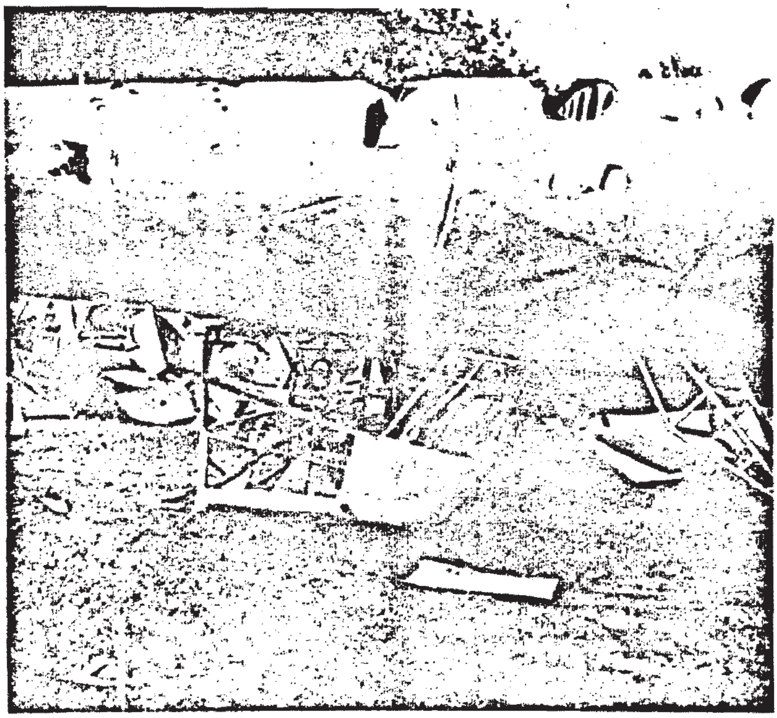


HORTEN PARABOLA

FIG. 24.



(a) 3/4 REAR VIEW SHOWING WING FORM.



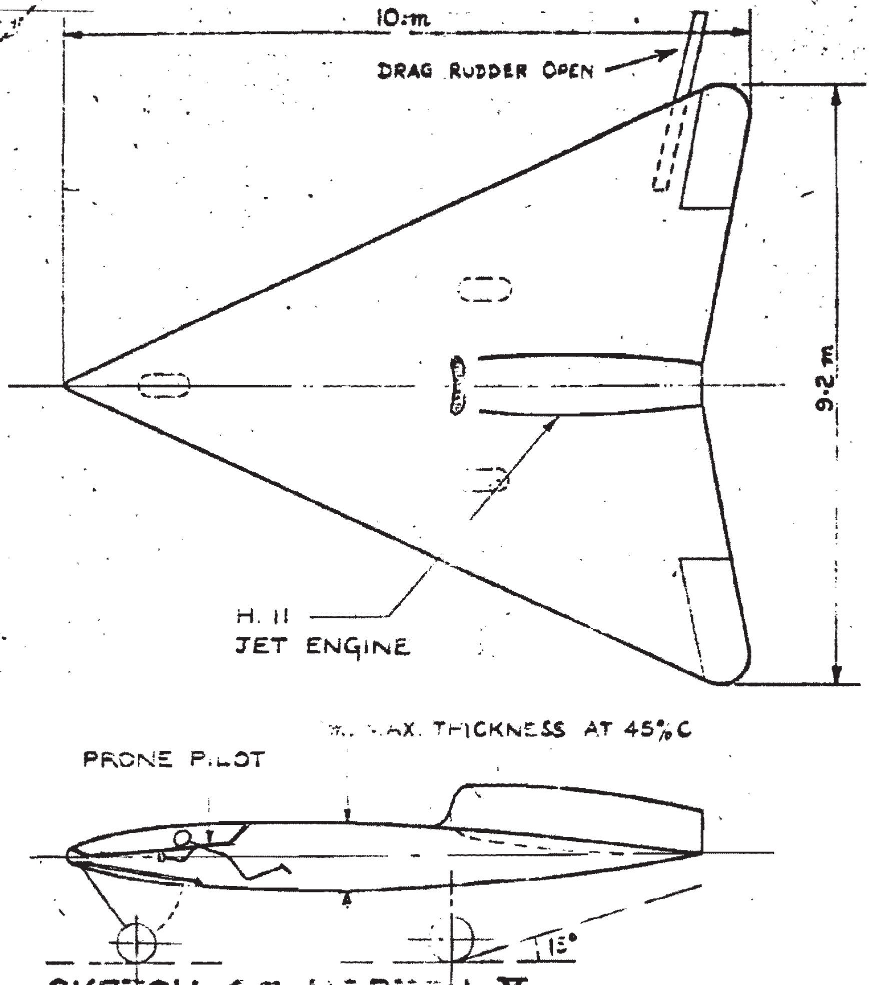
(b) 3/4 FRONT VIEW SHOWING HANGING STICK & PILOTS CABIN.

DAMAGED HORTEN XIII FOUND AT GOPPINGEN.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG No. 64878
DATE 5·9·45

R.17.902.S.
30-6-45

FIG. 25



SKETCH OF HORTEN X - APPROXIMATE ONLY

FIG. 26

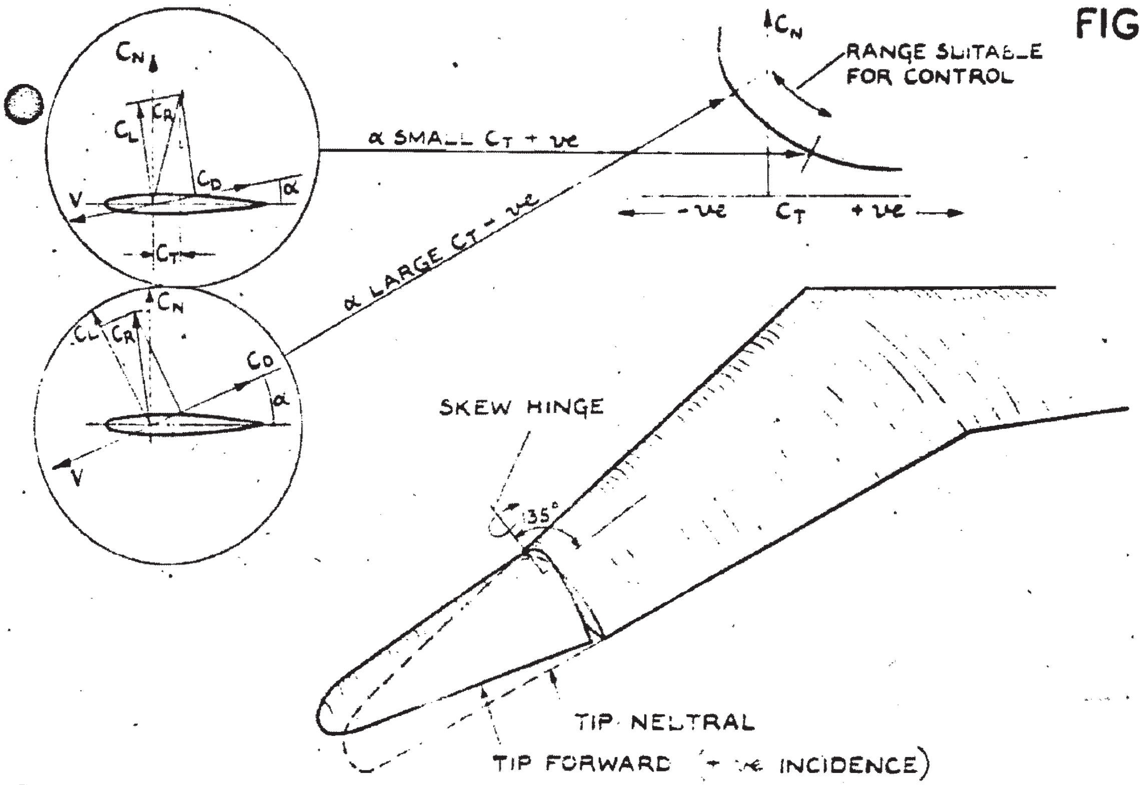
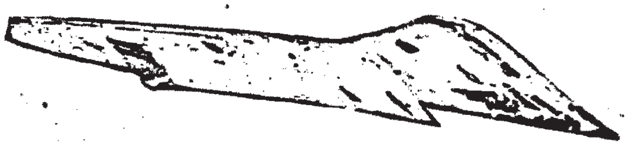
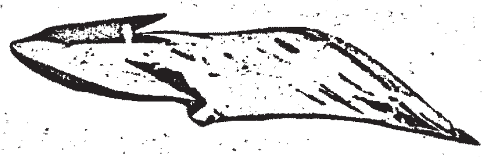


DIAGRAM OF WAGGLE TIP CONTROL - HORTEN IIIe

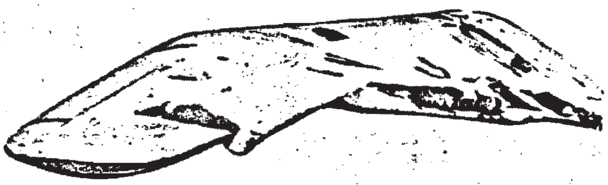
FIG.27.



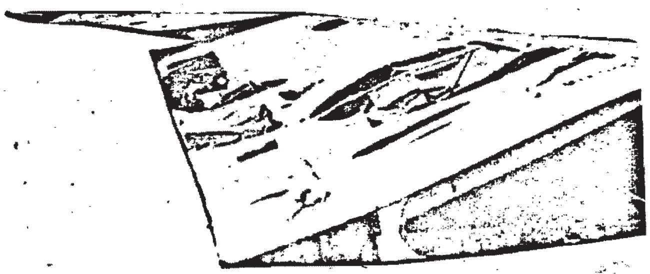
(a) TIP SWEPT FORWARD.



(b) TIP NEUTRAL - DRAG RUDDER OPEN.



(c) TIP SWEPT BACK.



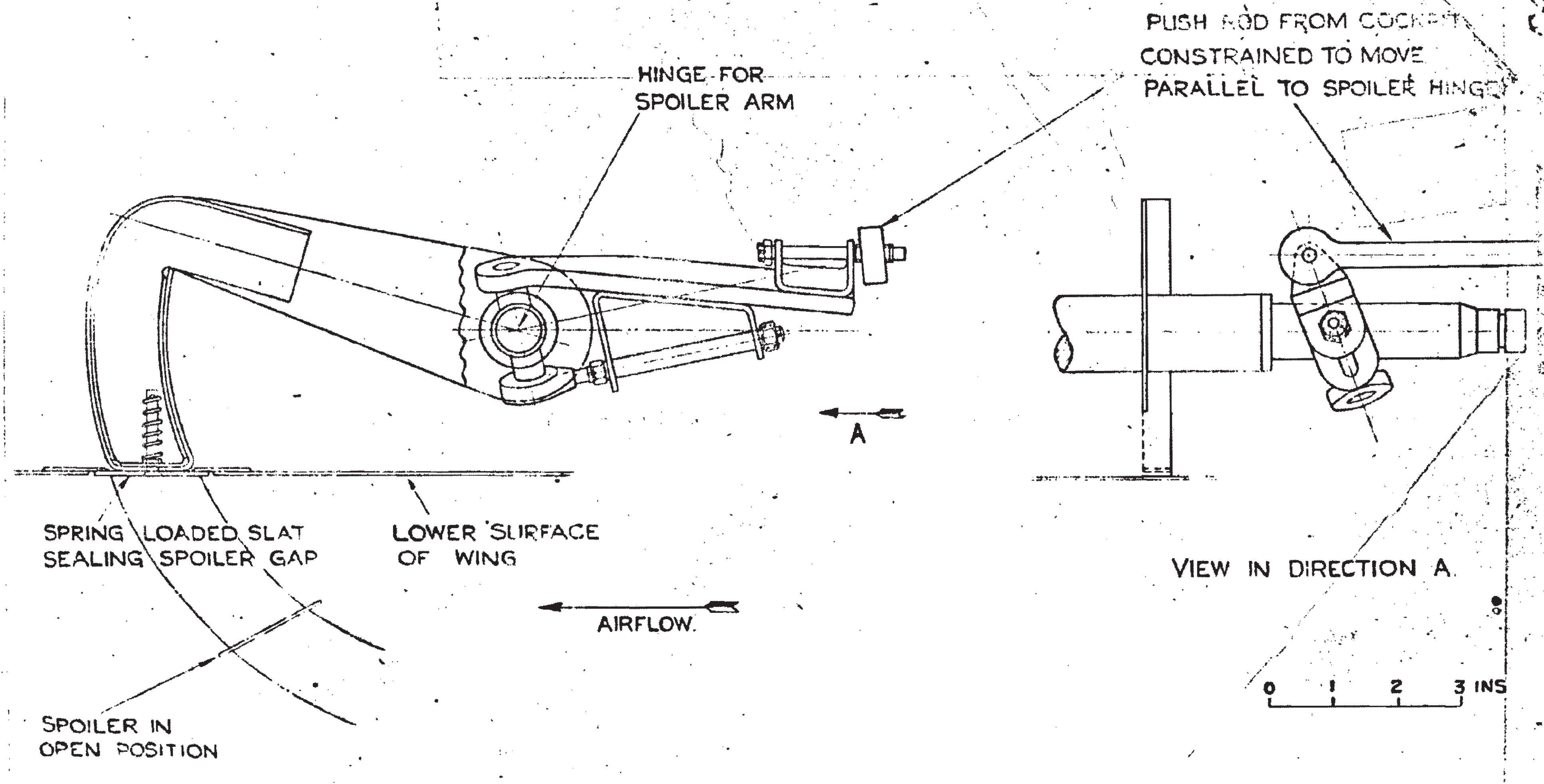
(d) TIP SWEPT BACK - VIEW FROM WING ROOT.

WAGGLE TIP CONTROL.

HORTEN IIIe.

ROYAL AIRCRAFT ESTABLISHMENT
PHOTOGRAPHIC DIVISION
COPY NEG. No. 65658.
DATE 12. 10. 45.

FIG. 28


HINGE FOR SPOILER ARM
PUSH ROD FROM COCKPIT CONSTRAINED TO MOVE PARALLEL TO SPOILER HINGE
A
SPRING LOADED SLAT SEALING SPOILER GAP
LOWER SURFACE OF WING
AIRFLOW.
SPOILER IN OPEN POSITION
VIEW IN DIRECTION A.
0
1
2
3 INS

LOWER HALF OF HORTEN IX DRAG RUDDER